THE AMERICAN JOURNAL OF ROENTGENOLOGY, RADIUM THERAPY AND NUCLEAR MEDICINE

VOL. 70 JULY, 1953 NO. 1

CONTENTS

Localized Thinning and Enlargement of the Cranium With Special Reference to the Middle Fossa . . . . ARTHUR E. CHILDE, M.D. 1

Occipitalization of the Atlas . . . . . D. L. MCRAE, M.D., AND A. S. BARNUM, M.D. 23

Agenesis of the Corpus Callosum with Concomitant Malformations, Including Atresia of the Foramens of Luschka and Magendie . . . . . EUGENE F. VAN EPPS, M.D. 47

Cerebral Angiography. Fundamentals in Anatomy and Physiology . . . . . PHILIP J. HODES, M.D., FRANCISCO CAMPOY, M.D., ... HELEN E. RIGGS, M.D., AND PAUL BLY, M.D. 61

Roentgenologic Recognition of Habenular Calcification as Distinct from Calcification in the Pineal Body—Its Application in Cerebral Localization . . . . . HERBERT M. STAUFFER, M.D., LEO B. SNOW, M.D., ... AND ANDREW B. ADAMS, M.D. 83

Chronic Ulcerative Granulomatous Jejunitis and Ileojejunitis . . . . . RICHARD H. MARSHAK, M.D., AND . . . . . BERNARD S. WOLF, M.D. 93

Orthoroentgenography . . . . . G. SCHALTENBRAND 114

Historoentgenography (Microradiography) of Impregnated Cancer Tissue . . . . . FEDOR BOHATIRCHUK, M.D., D.M.Sc. (Kiev) 119

Radioisotopes as Sources of Gamma Rays for Therapy . . . . . PAUL C. AEBERSOLD, Ph.D. 126

Roentgen-ray Motion Pictures by Means of Screen Intensification . . . . . RUSSELL H. MORGAN, M.D., AND RALPH E. STURM 136

Multifilm Cassette for Use in Laminagraphy . . . . . WALDRON M. SENNOTT, M.D., ... AND HOWARD E. WORRELL, Chief Technician 141

Interchangeable Mask and Compression Cones for Mucosal Relief . . . . MORIS HORWITZ, M.D., AND SIDNEY D. MESIROW, M.D. 143

Isodose Indicator . . . . . JOHN S. LAUGHLIN, Ph.D., AND WALTER J. HENDERSON, B.S. 146

Editorials

Pseudo-epiphyses in Hand and Foot . . ERNEST LACHMAN, M.D. 149

Ralph Davis Leonard, 1886–1952 . CHARLES W. BLACKETT, M.D. 152

James Millar Bonnar, 1878–1952 . . . MAX RITVO, M.D. 154

Society Proceedings, Correspondence and News Items 156

Book Reviews 163

Abstracts of Radiological Literature 166

GENERAL INFORMATION

Manuscripts offered for publication and other correspondence relating to the editorial management and books for review should be sent to Dr. Lawrence Reynolds, Editor, 110 Professional Building, Detroit 1, Michigan. Contributions may be sent in foreign languages and will be translated if found acceptable. Original articles are published with the understanding that they are contributed exclusively to THE AMERICAN JOURNAL OF ROENTGENOLOGY, RADIUM THERAPY AND NUCLEAR MEDICINE.

A certain number of illustrations will be supplied free of cost; but special arrangements must be made with the Editor and Publisher for excess illustrations and elaborate tables.

Fifty reprints are furnished without charge to authors. Additional reprints may be purchased according to a scale of prices that accompanies galley proofs.

Correspondence regarding subscriptions, advertisements, and other business relating to THE AMERICAN JOURNAL OF ROENTGENOLOGY, RADIUM THERAPY AND NUCLEAR MEDICINE should be addressed to Charles C Thomas, Publisher, 301–327 East Lawrence Avenue, Springfield, Illinois.

Issued monthly. Annual Subscription: United States, U. S. Possessions, Pan-American Union and Spain, $15.00; Canada and Newfoundland, $16.00; other foreign countries, $17.00. Current single numbers, $1.50. Distributed in the British Commonwealth of Nations by Blackwell Scientific Publications, Ltd., 24–25 Broad Street, Oxford, England. Yearly price £6.5.0.

Manuscripts should be typewritten, with double spacing, and good margins (not on thin paper) and the *original* should be sent to the Editor. The author should keep a carbon copy, as the original is not returned. The name of the author should appear on each sheet of manuscript. Tabular materials should be typed on separate sheets: likewise bibliographical lists, footnotes, etc.

Drawings and charts for reproduction should be made in black (*never* in blue). Photographic prints of plates or slides on glossy paper produce the best half-tones.

All photographs and drawings intended for illustrations should be numbered, the top plainly indicated, and an abbreviated title of the paper placed on the back of *each one*.

Legends for illustrations should be typewritten in a single list, double spaced, with numbers corresponding to those on the photographs and drawings, instead of attaching each legend to its corresponding figure.

Care in preparation of bibliographies will save much time and correspondence. Each reference in a bibliography should include the following information in the order indicated: Name of the author with initials; title of the article; name of the periodical; year, volume, and pages. It is requested that the authors use the following as model:

1. Olcott, C. T., and Dooley, S. W. Agenesis of the lung of an infant. Am. J. Dis. Child., 1943, 65, 766–780.

The month should be given if the reference is to an issue of the current year. An alphabetical arrangement of authors is preferred.

The author should always place his full address somewhere on his manuscript. This is very important and is often omitted.

For information regarding membership in the American Roentgen Ray Society, address the Chairman of the Executive Council, Dr. Clyde A. Stevenson, Scott and White Clinic, Temple, Texas.

For information regarding the program of the annual meeting of the American Roentgen Ray Society, address the President-Elect, Dr. Harry M. Weber, Mayo Clinic, Rochester, Minnesota.

For information regarding membership in the American Radium Society, address the Secretary, Dr. Robert E. Fricke, Mayo Clinic, Rochester, Minnesota.

For information regarding the program of the annual meeting of the American Radium Society, address the President, Dr. Edith H. Quimby, 630 West 168th St., New York 32, New York.

THE AMERICAN JOURNAL OF ROENTGENOLOGY, RADIUM THERAPY AND NUCLEAR MEDICINE is owned, maintained by, and in the interests of, the American Roentgen Ray Society, Inc. It is issued monthly by Charles C Thomas, Publisher, 301–327 East Lawrence Avenue, Springfield, Illinois. THE AMERICAN JOURNAL OF ROENTGENOLOGY, RADIUM THERAPY AND NUCLEAR MEDICINE does not hold itself responsible for any statements made or opinions expressed by any contributors in any article published in its columns.

Entered as second-class matter February 10, 1930, at the postoffice at Springfield, Illinois, and Menasha, Wisconsin, under the Act of March 3, 1879. Accepted for mailing at the special rate of postage provided for in the Act of February 28, 1925, embodied in Paragraph 4, section 538, P.L. and R. authorized February 10, 1930. Delivery is not guaranteed. Replacements are not guaranteed nor promised, but will be attempted if extra single copies are available and only if requested within 30 days from first of month following publication (17th of month) for domestic subscribers and 60 days for foreign subscribers. A 30 day notice of a change of address is requested. When ordering a change of address, send the Publisher both the old and new address.

Copyright 1953 by American Roentgen Ray Society, Inc. All rights reserved. This issue may not be reproduced, in whole or in part, in any form (except by reviewers for the public press) without written permission from the publisher. Copyrighted in the British Commonwealth by Blackwell Scientific Publications, Oxford. No part may be duplicated or reproduced without permission of publishers.

PRINTED IN U.S.A.

THE AMERICAN JOURNAL OF ROENTGENOLOGY
RADIUM THERAPY AND NUCLEAR MEDICINE

VOL. 70 JULY, 1953 No. 1

LOCALIZED THINNING AND ENLARGEMENT OF THE CRANIUM

WITH SPECIAL REFERENCE TO THE MIDDLE FOSSA*

By ARTHUR E. CHILDE, M.D.
WINNIPEG, CANADA

ALTHOUGH localized thinning and enlargement of the cranium are uncommon, they are encountered sufficiently often to justify re-examination of some of the causes and to add another which does not seem to have been described previously. When the occurrence of such roentgenographic signs is more widely known, it is quite probable that they will be recognized more frequently.

Davidoff and Dyke[3] in 1938 reported a condition which they called relapsing juvenile chronic subdural hematoma. They described their findings in 4 patients between six and eighteen years of age with histories of head injuries five to eleven years previously and more recent trauma two to twelve months before admission. The roentgenographic changes consisted of elevation of the sphenoid ridge, superior orbital plate and superior orbital ridge, deepening, widening and lengthening of the middle fossa, disappearance or indistinctness of the oblique line delineating the posterolateral wall of the bony orbit, atrophy of the inferior and lateral wall of the superior orbital fissure, hypertrophy of the frontal and ethmoidal sinuses and unilateral thickening of the skull. Subdural hematomas were present in all 4 cases.

The following year Hardman[6] reported 3 children ranging in age from five to twelve years who presented cranial asymmetry due to subdural collections of fluid. Two had subdural hematomas, but the third, who evidently came under observation only because a swelling of his forehead was discovered, had a subdural "hydroma."

Dandy[2] in 1946 reported a case of a boy with a huge subdural "hydroma" resulting from a fall four months previously. There was a bulging subtemporal decompression, but no cranial asymmetry was noted. He assumed that it was due to a tear in the arachnoid and a valve action.

In 1949 Bull[1] reported 9 cases with localized bulging of the skull. He described elevation of the lesser wing of the sphenoid, outward bulging of the greater wing and forward bulging of the middle fossa. Two of his cases were asymptomatic and both of these had subdural "hygromas." The other 7 cases had subdural hematomas, and all the patients in this group had

* Presented at the Fifty-second Annual Meeting, American Roentgen Ray Society, Washington, D. C., Sept. 25–28, 1951.

symptoms usually indicative of increased intracranial pressure. He was unable to find the other roentgenographic changes noted by Davidoff and Dyke.

Jupe[7] in 1938 stated that in children under the age of fifteen years, it is possible to get localized bulging of the skull over a tumor and he illustrated this condition involving the temporal bone and probably the middle fossa in a young boy due to an adjacent astrocytoma. He also illustrated thinning of the parietal bone of an adult due to an astrocytoma, but he said that it is unusual to get considerable local bulging in this age group except in young adults in whom the process is assumed to have existed since childhood or early youth. If bulging is present it is very slight as compared to that in the child.

Orley[9] (1949) reproduced the roentgenogram of a girl, aged fifteen years, who had a bulging, thinned temporal bone due to a cystic temporal glioma. It is also evident from the illustration that there was elevation of the lesser wing of the sphenoid.

LeWald[8] (1933) reported 4 cases of congenital absence of the superior orbital wall associated with pulsating exophthalmos. Two of these also had lesions due to the presence of diffuse neurofibromatosis. He mentioned several other similar cases in the literature. Dyke[5] (1941), in discussing neurofibromatosis, stated that there might be marked enlargement of one middle fossa in this condition. The greater wing of the sphenoid as well as the posterior portion of the superior orbital plate might be absent and the orbit enlarged with thinning of the bony walls. In such cases the sella turcica might be enlarged and thinned, and the floor displaced ventrally. Pfeiffer[10] (1943) reported 7 cases of neurofibromatosis of the orbit, 2 of which had pulsating exophthalmos.

REPORT OF CASES

The material in this paper consists of 13 cases which may be subdivided into five main categories.

A. *Subdural Collections of Fuid*

1. *Chronic Subdural Hematoma.*

CASE 1. L. G., a white male, aged nine, was admitted to the Winnipeg General Hospital on May 5, 1948, under the care of Dr. Harry Medovy. For four months there had been vomiting and attacks of headaches confined to the left frontal region. There had also been three episodes of numbness and twitching of the right arm and face. Personality changes had developed about two or three years before. Examination revealed obvious swelling of the left temporal region covering an area about 6 to 8 cm. in diameter. There was bilateral papilledema. His I.Q. (Wexler) was 130. An electroencephalogram showed widespread cerebral involvement most marked in the left temporoparietal area.

Roentgenograms of the skull (Fig. 1*A* and *B*) revealed the entire cranium to be rather large. The left middle fossa was enlarged markedly forward and downward and the squama of the left temporal bone was thinned and bulged laterally. There was similar thinning and bulging of the anterior inferior part of the left parietal bone and of the adjacent posterior part of the left side of the frontal bone. The posterolateral margin of the left orbit was indistinct and there was elevation of the lesser wing of the sphenoid. There was some thickening of the left side of the skull above the thinned area. The sella turcica was not demineralized and the sinuses and mastoids on the left side were not hypertrophied. Comparison with films made elsewhere on September 10, 1945, suggested that there had been very little change in that interval.

Operation six days later by Dr. Hugh Cameron revealed the dura to be bluish and to protrude locally. A large subdural hematoma was present, some of it considerably more recent than the remainder. The left frontal lobe was found to be almost completely nonexistent, but the left temporal lobe, which was also markedly compressed, expanded to some extent when the hematoma was removed.

The boy made an uneventful recovery and there have been no further complaints. His personality has returned to normal.

Comment. This case resembles very closely the 4 cases reported by Davidoff and Dyke, 2 of the cases of Hardman and

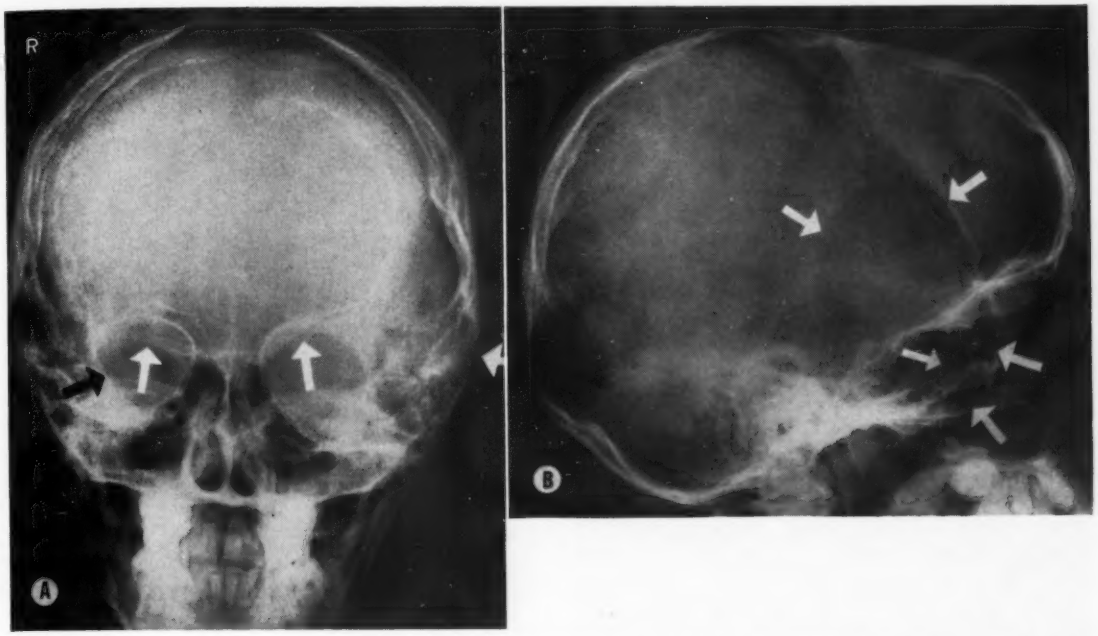


Fig. 1. Case 1. Chronic Subdural Hematoma. Patient, aged nine. (*A*) The squama of the left temporal bone is thinned and bulges laterally (arrow) and the posterolateral margin of the left orbit is indistinct. There is elevation of the lesser wing of the sphenoid (arrow). The superior part of the cranium on the left side is slightly thickened. (*B*) The left middle fossa is enlarged markedly forward (anterior arrows) in comparison to the right (posterior arrow). There is also thinning of the left temporal, the left side of the frontal and the left parietal bones (upper arrows). No deformity of the sella turcica is shown.

7 of the cases described by Bull. The roentgenographic changes in the plain films visible at the time of admission to hospital were known to have been present nearly three years previously, and it is reasonable to assume they had been present much longer than that. The onset of symptoms of increased intracranial pressure was evidently recent and can probably be explained on the basis of a fresh subdural hematoma, superimposed on one of long standing, possibly originating at birth.

2. *Chronic Subdural Hygroma.*

Case II. D. B. (No. 4336), a white female, aged eight, was admitted to the Montreal Neurological Institute on January 22, 1939. There had been attacks of unconsciousness with vomiting and left facial weakness, twitching of the face, and left sixth nerve weakness when she was twenty months old. Swelling of the upper and lower lids of the left eye had occurred from the age of three to six years. Definite exophthalmos had been noted when she was five years old. This changed in severity and was accompanied by temporal and supra-orbital headaches.

Examination revealed slight proptosis and swelling of the left upper lid. The left eye protruded about 5 mm. and there was slight internal strabismus.

Roentgenograms of the skull (Fig. 2*A* and *B*) showed that the floor of the left middle fossa bulged markedly downward although there was hardly any forward enlargement. The outer portion of the lesser wing of the sphenoid on this side was less distinct than normal, but the posterolateral margin of the orbit was intact. There was no bulging or thinning of the squama of the left temporal bone. The left superior orbital fissure was considerably broadened and the left anterior clinoid was displaced slightly upward and forward.

Operation by Dr. Wilder Penfield on February 1, 1939, uncovered a cyst full of yellow fluid under the left temporal lobe. It filled the floor of the middle fossa and extended from the back of the orbit to the petrous ridge.

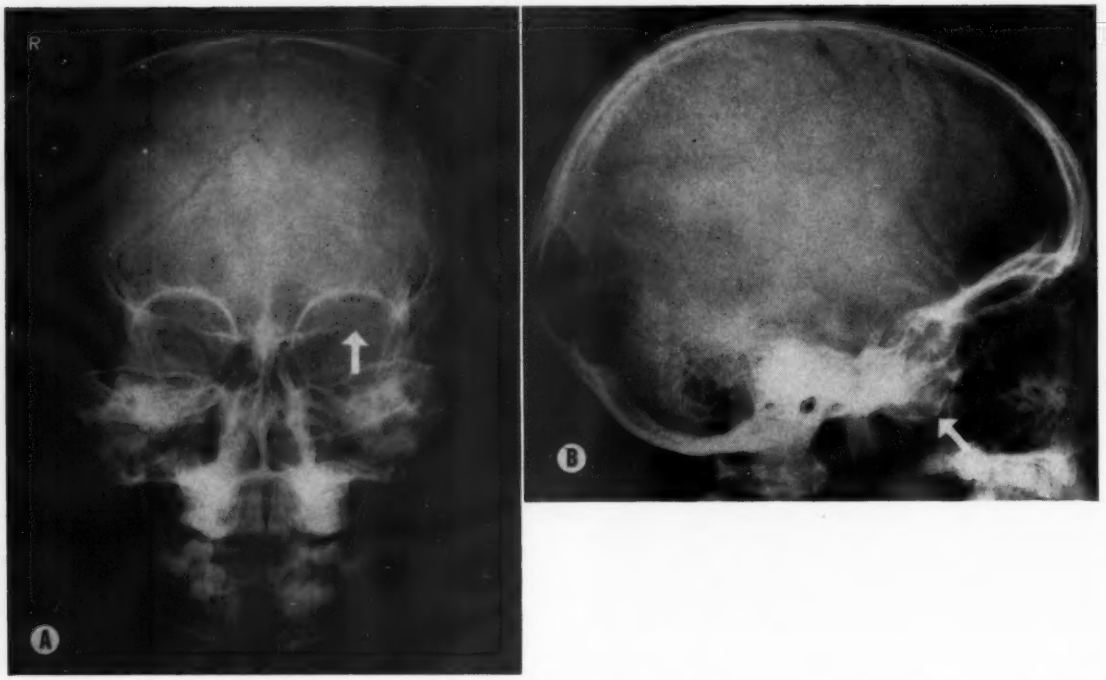


FIG. 2. Case II. Chronic Subdural Hygroma. Patient, aged eight. (*A*) The outer portion of the lesser wing of the sphenoid on the left side is indistinct (arrow) but the posterolateral margin of the orbit is not abnormal in appearance. There is broadening of the left superior orbital fissure. (*B*) The floor of the left middle fossa bulges considerably downward (arrow), but it is not enlarged forward.

There was a rather heavy lining membrane so that the roof appeared very much like the dura. Analysis of the fluid in the cyst showed the proteins to be 21 mg. and the sugar 80 mg. per 100 cc. Dr. Penfield concluded that it was a subdural cyst, probably the end result of a subdural hematoma. He thought that the continuous pressure within this cyst had subjected the structures of the orbit to increased pressure from behind.

No improvement in the sixth nerve paralysis resulted and Dr. Penfield again explored the left middle fossa on June 26, 1940. The cyst had reformed apparently because the space it occupied was not needed by the temporal lobe. The sixth nerve could not be found but the roof of the cyst was again removed widely.

Paralysis of her sixth nerve has persisted but she is otherwise well and Dr. Penfield states that she has learned to hold her head in such a manner that no one would suspect this abnormality.

Comment. The symptoms from which this girl suffered dated back to the age of twenty months and it seems certain that they were caused by the cyst in the left temporal region. Dr. Penfield concluded that it was located in the subdural space and very possibly the end result of a subdural hematoma, in spite of the fact that its contents were not bloody. The bone changes were quite striking, but very localized.

CASE III. B. H. (No. 45-4671), a white female, aged nineteen, was admitted to the Montreal Neurological Institute on April 9, 1945. She complained of a protrusion of the skull in the right frontotemporal region which she believed had been present since birth but which was said to have become more marked in the preceding two years. Episodes of severe headaches had occurred for the previous eight months, and they had been worse for four months. There had also been attacks of severe, sharp, shooting pain in the right temporal region for four months.

Examination showed this bony protrusion to be about 1.5 cm. in height. Neurological examination was essentially negative except for a slightly hyperactive ankle jerk on the right

side and bilaterally hyperactive knee jerks.

Roentgenograms of the skull (Fig. 3*A* and *B*) indicated that there was considerable forward enlargement of the right middle fossa and a good deal of elevation of the lesser wing of the sphenoid. The posterolateral wall of the orbit was indistinct. There was striking thinning and outward bulging involving the anterior part of the right parietal bone and the adjacent portion of the right side of the frontal bone. The margins of this thinned area were scalloped and for the most part rather sharply outlined.

Right osteoplastic craniotomy (Fig. 3*C*, *D* and *E*) by Dr. Wilder Penfield on April 11, 1945, showed the bone to be elevated and so thin that light would shine through it. Deep to this elevated area the dura was thinned out greatly and beneath this thinned dura there was a cyst which was probably in the subdural space, although it seemed to be in the subarachnoid space. Over the surface of the cyst there was a delicate membrane not any thicker than ordinary arachnoid and around its periphery there was a dense scarred adhesion, between the arachnoid and the dura. The cystic space extended down into the fissure of Sylvius, separating the temporal and frontal lobes, so that the island of Reil was exposed. There was no thickening and no evidence of inflammation. Dr. Penfield decided that the cyst had been present for a long time, and that it had either pushed the temporal lobe away from the fissure of Sylvius or that it was present so early in development that the temporal lobe had not closed over the island of Reil. He thought that there was evidence of intracystic pressure early in life, which served to thin the bone out and displace the brain tissue. This would favor a subdural hematoma, which became cystic and the contents were probably first blood, then fluid high in protein gradually changing over into cerebrospinal fluid. It was felt that at the time of operation there was no longer any increase in pressure and that the cyst was then completely benign.

Comment. In this case the prominence of the skull evidently dated back to very early life, although it is possible that it had become slightly more marked in the previous two years. The pronounced thinning of the bone and compression of the brain might be considered surprising in view of the thinness of the cyst wall, but the same features appear in the following 5 cases and evidently are to be expected with such a lesion. It is fair to assume that changes of this magnitude could only occur as a result of a lesion which originated either at birth or quite early in life.

Case iv. F. M. (No. 15738), a white female, aged twenty-four, was admitted to the Winnipeg General Hospital on January 15, 1949. She complained of a swelling of the left frontoparietal region which she said had been present since she was eight years old. There was no pain or tenderness and she did not suffer from headache, dizziness or eye symptoms. She thought that she had been struck on the head with a baseball bat many years before.

Examination was completely negative apart from the prominence of the head on the left side.

Roentgenograms of the skull (Fig. 4*A*, *B* and *C*) showed the left middle fossa to be enlarged forward markedly. They also disclosed thinning and outward bulging involving the squama of the left temporal bone and of the adjacent parts of the left parietal bone and the left side of the frontal bone. The left anterior clinoid was displaced moderately forward and there was definite elevation of the sphenoid ridge on the left side. The posterolateral margin of the left orbit was less distinct than normal.

Operation by Dr. Hugh Cameron on January 18, 1949, revealed the dura underlying the thinned and bulging temporal, frontal and parietal bones to be very blue. Beneath this there was a large quantity of clear fluid which had compressed the frontal and temporal lobes to a marked degree. There was no membrane in the dura and there was no constricting membrane to limit brain expansion. He did not feel that the fluid-filled cavity communicated with the general subarachnoid space or with the ventricular system. Analysis of the cyst fluid showed the total protein to be 25 mg. per 100 cc. It contained 607 red blood cells and no white blood cells.

Comment. This case is interesting in that the only complaint was the prominence of the cranium and there were no other clinical findings. In spite of this, the bone changes were striking and at operation it was found that there had been marked compression of the frontal and temporal

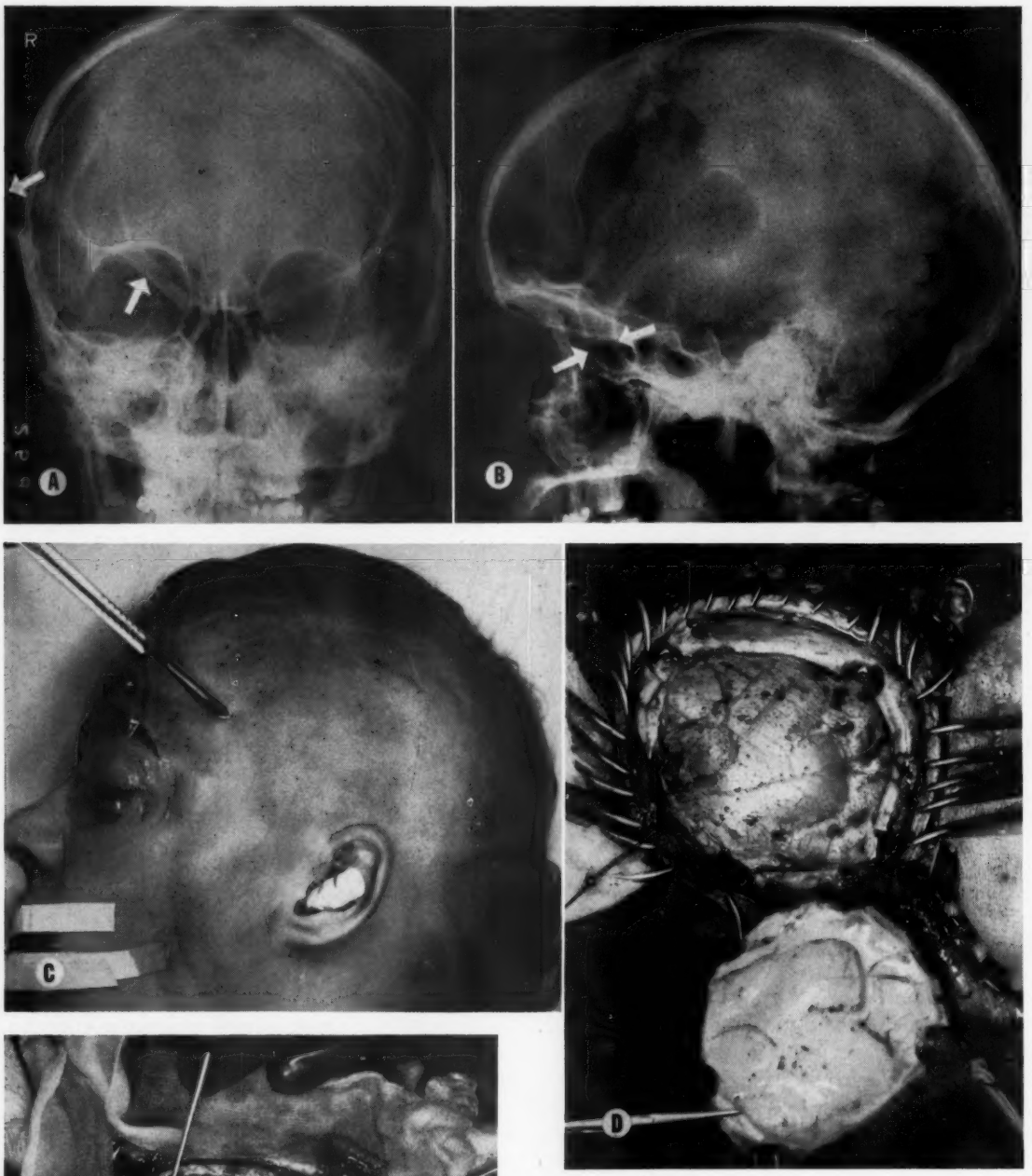


Fig. 3. Case III. Chronic Subdural Hygroma. Patient, aged nineteen. (*A*) The posterolateral wall of the right orbit is indistinct and there is considerable elevation of the lesser wing of the sphenoid (arrow). There is thinning and outward bulging of the right parietal bone and of the right side of the frontal bone (upper arrow).

(*B*) The right middle fossa is enlarged forward (anterior arrow) in relation to the left middle fossa (posterior arow). Note the thinned area with somewhat scalloped margins involving the adjacent portions of the right parietal bone and the right side of the frontal bone.

(*Continued on next page*)

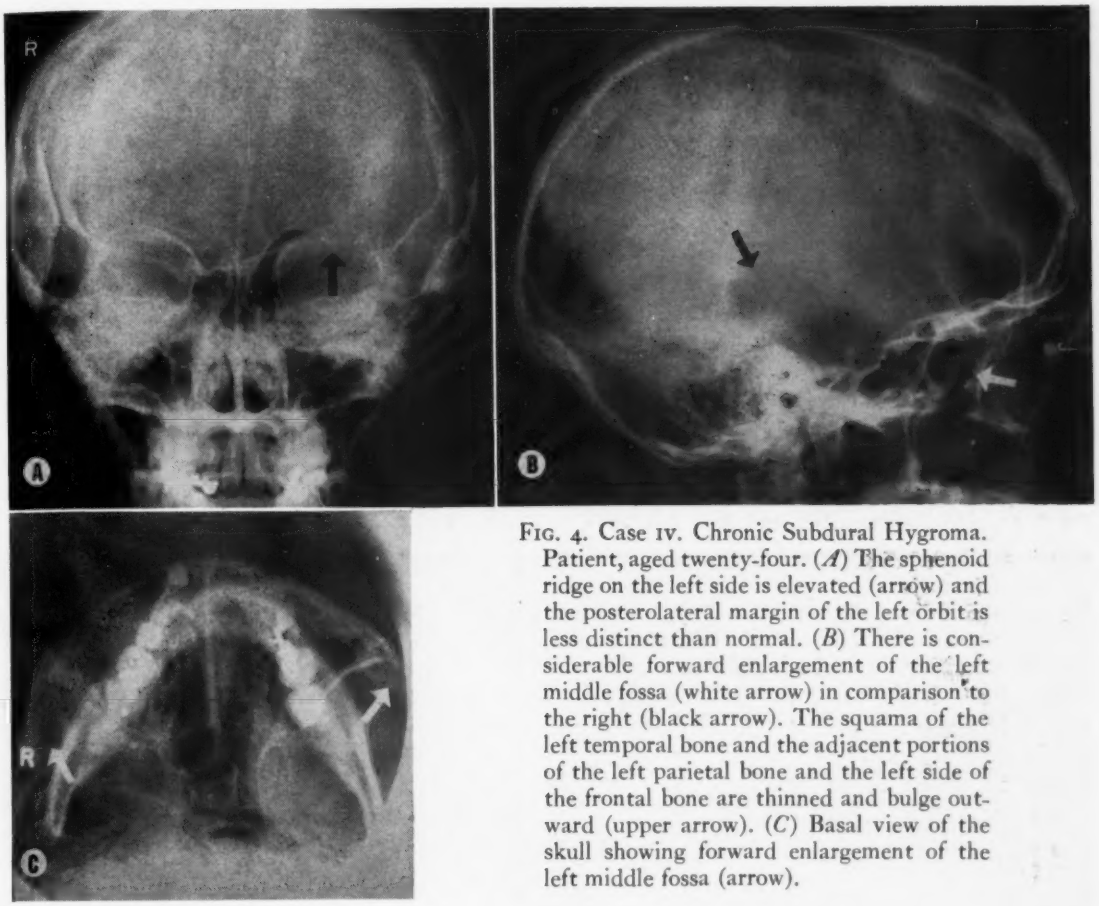


Fig. 4. Case iv. Chronic Subdural Hygroma. Patient, aged twenty-four. (*A*) The sphenoid ridge on the left side is elevated (arrow) and the posterolateral margin of the left orbit is less distinct than normal. (*B*) There is considerable forward enlargement of the left middle fossa (white arrow) in comparison to the right (black arrow). The squama of the left temporal bone and the adjacent portions of the left parietal bone and the left side of the frontal bone are thinned and bulge outward (upper arrow). (*C*) Basal view of the skull showing forward enlargement of the left middle fossa (arrow).

lobes. The history indicates that the lesion was well developed when she was eight years old and it probably was present much longer than that.

Case v. H. L. (No. A-37947), a white male, aged twenty-one, was admitted to the Winnipeg General Hospital on October 16, 1950. About six weeks before admission, after swimming, he shook his head to get his hair away from his eyes. He felt a snap in the left side of his head and almost immediately noticed a pain in both eyes which in about two hours spread upward to involve the whole of the left side of his head. He was nauseated and vomited. Following admission to another hospital, the headache gradually resolved so that he was discharged five weeks later and allowed to stay at home one week before coming to Winnipeg. There had never been any previous episodes of headache and he had never suffered from convulsions, weakness, dizziness or paresis. He had been able to work hard on a farm which had necessitated missing considerable school, but in spite of this he had finished Grade 12 and planned to go to college.

At the age of three years he had fallen out of a high chair and struck his left forehead and about this same time a protuberance had first been noted here. When he was fourteen years old he had been kicked by a horse in the same area and he was hit here again, this time by a baseball bat, one year later. No further attention was paid to the prominence after it was pronounced innocent by the local physician.

(*C*) Preoperative photograph (mirror image) showing the cranial bulge and the site of the incision in the scalp.

(*D*) The bone flap has been elevated and the inner table of the skull is seen to be thinned and to bulge outward. The thinned bulging dura is also visible.

(*E*) Following removal of the dura, the thin-walled cystic area is evident. Note the arachnoid-like wall and the compression of the adjacent brain.

Examination revealed marked prominence of of the left frontal region and prominence of the whole left side of the skull. The right pupil was slightly larger than the left but both reacted to light and accommodation and there was no nystagmus. The motor power of the right seventh and eleventh cranial nerves was slightly greater than the left, but there was no demonstrable difference on the two sides in the third, fourth, fifth, sixth, tenth or twelfth cranial nerves or in the limbs. There was no rhombergism, adiadochokinesis or past pointing and the position sense was not disturbed.

Roentgenograms of the skull (Fig. 5*A* and *B*) showed the cranium to be large without evidence of separation of the sutures or convolutional atrophy. The left middle fossa bulged markedly forward and the roof of the left orbit was considerably depressed. Thinning and marked outward bulging involved the left side of the frontal bone and the squama of the left temporal bone. The left anterior clinoid was missing and there was a large clearcut downward bulge in the anterior one-third of the sella turcica.

Cerebral angiography (Fig. 5*C*) demonstrated that the left anterior cerebral branches were displaced posteriorly and well to the right, and that the middle cerebral branches were displaced markedly medially and upward.

Craniotomy by Dr. Dwight Parkinson on October 19, 1950, uncovered a huge bipolar cystic hygroma involving the left anterior and middle cranial fossae. Both internal carotid arteries, both optic nerves, the left anterior and middle cerebral arteries, the left side of

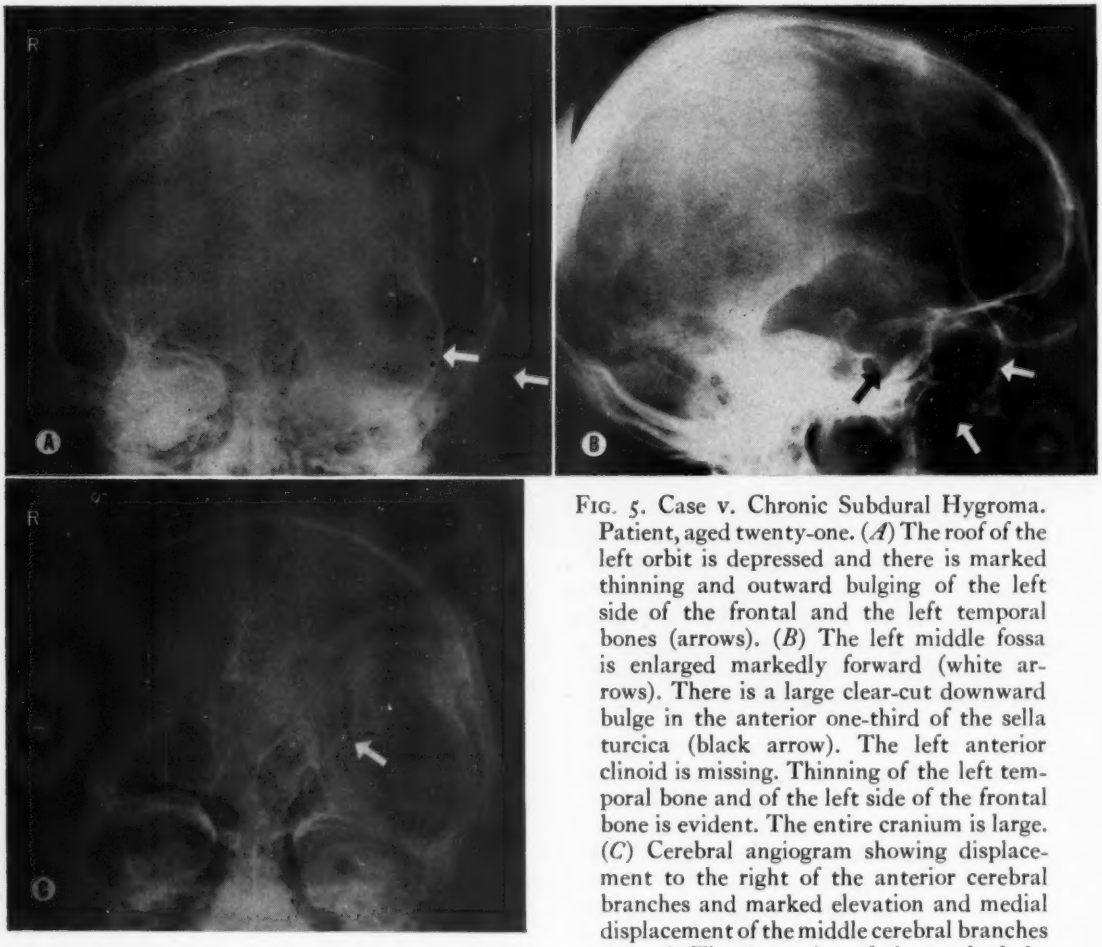


Fig. 5. Case v. Chronic Subdural Hygroma. Patient, aged twenty-one. (*A*) The roof of the left orbit is depressed and there is marked thinning and outward bulging of the left side of the frontal and the left temporal bones (arrows). (*B*) The left middle fossa is enlarged markedly forward (white arrows). There is a large clear-cut downward bulge in the anterior one-third of the sella turcica (black arrow). The left anterior clinoid is missing. Thinning of the left temporal bone and of the left side of the frontal bone is evident. The entire cranium is large. (*C*) Cerebral angiogram showing displacement to the right of the anterior cerebral branches and marked elevation and medial displacement of the middle cerebral branches (arrow). The depression of the roof of the left orbit and the thinning and bulging of the left side of the frontal and the left temporal bones are again shown.

the tentorium, the left gasserian ganglion, the left third nerve and all of the left anterior and middle fossae were exposed when this was emptied. The anterior part of the sella turcica was seen to be ballooned downward. Following evacuation of the hygroma, the bulging supraorbital region was replaced with a tantalum plate to decrease the deformity.

Comment. The bone changes and the defective development of the left cerebral hemisphere were the most extreme that we have so far encountered in this condition. There was a history of injury at the age of three years which could have been responsible, although the story of a cranial bulge at this time suggests that the hygroma may have been present even before this. However, a boy of eight years of age in Hardman's series who had a subdural hematoma was said to have developed a skull deformity in nine weeks. The cause of the acute headache which developed six weeks before our patient was admitted cannot be established with certainty, but possibly it was due to hemorrhage which had resolved by the time of operation. In spite of the extreme loss of brain substances, his intelligence was not seriously impaired and there were surprisingly few neurological findings.

Case vi. R. K. (No. 50-3151), a white female, aged eighteen, was admitted to the Children's Hospital of Winnipeg on November 28, 1950. There had been a left hemiparesis since birth. At the age of three years a hemangioma had been removed from the left cheek and the left tendo achillis had been lengthened.

Examination showed weakness and atrophy of the left leg and, to a lesser extent, of the left arm. She was unable to flex her left fingers. The left plantar reflex was extensor. In spite of her disability she managed to get along quite well.

Roentgenograms of the skull (Fig. 6*A*) showed no asymmetry of the outer table. In the right parietal bone, extending as far forward as the coronal suture, there was a well defined, smooth, localized thinning of the inner table and diploë, involving an area about 6 cm. in diameter. No enlargement of the middle fossa was visible and there was no deformity of the lesser wing of the sphenoid or of the posterolateral wall of the orbit.

Pneumoencephalography (Fig. 6*B* and *C*) showed minimal enlargement of the left lateral ventricle. The right temporal horn was quite large and there was considerable upward and outward enlargement of portions 3 and 4 (middle and posterior thirds of the body) of the right lateral ventricle. There was a small localized bulge in the lateral wall of portion 3 (middle third of body) on the right side and there was also a small rounded defect in the inferior part of portions 1 and 2 (anterior horn) of the right lateral ventricle. The third ventricle and septum pellucidum measured slightly to the left of the midline. Normal appearing cortical markings were present over the left cerebral hemisphere but there was comparatively little filling of the subarachnoid space on the right side.

Operation by Dr. Hugh Cameron when a right parietal bone flap was turned down revealed the dura to be bluish and somewhat distended. When this was opened there was found to be an opaque membrane, which seemed continuous with the arachnoid over the upper cerebral convolutions, enclosing a cystic cavity filled with clear fluid. This cavity extended deeply inward as far as the wall of the lateral ventricle, although it did not communicate with it. The right parietal lobe was small and rudimentary and the frontal and temporal lobes were considerably compressed.

Comment. The history goes back to birth but it is not clear whether there was a birth injury. This is the only case of the hygroma series in which there was no deformity of the middle fossa and it is also the only case in this group in which there was no bulging of the outer table although the inner table and diploë were greatly thinned. The size of the hygroma and the extent of the brain compression were surprising in view of the relatively slight ventricular deformity, the majority of which suggested atrophy rather than a space occupying lesion.

Case vii. M. O., a white male, aged nine, was seen by Dr. Exum Walker of Atlanta, Georgia, on August 11, 1949, following a bicycle accident. Physical examination revealed an irregular laceration of the scalp about 3 cm.

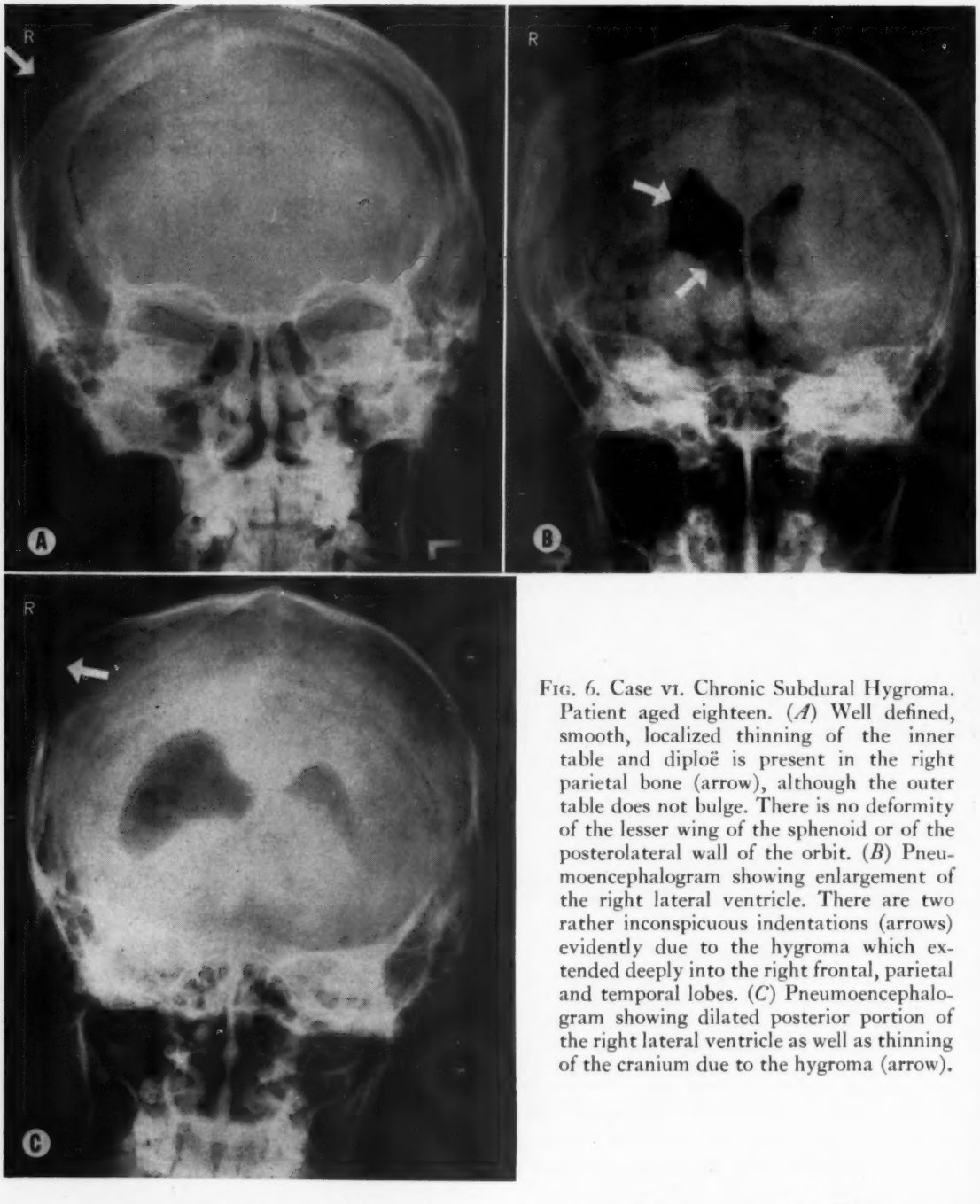


Fig. 6. Case VI. Chronic Subdural Hygroma. Patient aged eighteen. (*A*) Well defined, smooth, localized thinning of the inner table and diploë is present in the right parietal bone (arrow), although the outer table does not bulge. There is no deformity of the lesser wing of the sphenoid or of the posterolateral wall of the orbit. (*B*) Pneumoencephalogram showing enlargement of the right lateral ventricle. There are two rather inconspicuous indentations (arrows) evidently due to the hygroma which extended deeply into the right frontal, parietal and temporal lobes. (*C*) Pneumoencephalogram showing dilated posterior portion of the right lateral ventricle as well as thinning of the cranium due to the hygroma (arrow).

above the left eyebrow. Neurological examination was completely negative.

Roentgenograms of the skull (Fig. 7) showed a depressed comminuted fracture involving an area about 1 by 2 cm. in the left anterior frontal region, just above the outer part of the orbit. The left middle fossa was enlarged anteriorly and the posterolateral wall of the left orbit was indistinct superiorly. There was no appreciable elevation of the lesser wing of the sphenoid. The squama of the left temporal bone, the posterior part of the left side of the frontal bone and the adjacent anterior inferior part of the left parietal bone bulged outward and were thinned markedly. This thinned area had a very distinct curved anterior margin

situated just posterior to the depressed fracture. The sella turcica was not deformed and no asymmetry of the sinuses or mastoids was evident.

Further examination of the patient disclosed a prominence of his skull corresponding to the thinned area seen in the roentgenograms. The parents stated that this had been present for several years but they were not sure when it first appeared. They also said that he had been rather difficult to manage and presented an unexplained behavior problem.

Fig. 7. Case VII. Chronic Subdural Hygroma. Patient, aged nine. There is a small depressed comminuted fracture in the anterior part of the left side of the frontal bone (arrow). Just posterior to this the frontal, parietal and temporal bones are thinned and bulged outward. The anterior margin of this thinned area is quite sharply outlined.

Operation by Dr. Walker on August 19, 1949, confirmed marked thinning of the bone in this region. It was intact everywhere, but inferiorly it was scarcely thicker than roentgen film and could be cut with a pair of scissors. A large cystic cavity filled with fluid resembling cerebrospinal fluid was present immediately beneath the dura. It was lined with a thin capsule of tissue which looked like arachnoid, and it was situated exactly over the sylvian cleft. The frontal pole was displaced foreward and the temporal pole backward. The sphenoid ridge was exposed to within 3 or 4 mm. of the left anterior clinoid and several of the arterial vessels of the sylvian group were standing out alone fully 2 or 3 cm. from the displaced cerebral tissue. About the periphery of the cyst, the lining covering the brain was adherent to the dura exactly like that encountered in chronic subdural hematoma.

Comment. In this case it is possible that the hygroma was responsible for the behavior problem but otherwise it evidently caused no symptoms, even though it was quite large.

Case VIII. C. W., a white female, aged six, was referred to Dr. Exum Walker of Atlanta, Georgia, on August 19, 1950, because of a bony prominence in the right temporal region. This was known to have been present for three months. There had been complaints of headaches almost every day during this period, for which she had taken considerable amounts of aspirin.

Examination revealed a large, hard, bony prominence in the right temporal region immediately anterior to and above the ear. There were no abnormal cranial or peripheral neurologic findings, neither was there a history of convulsions or of weakness of any of the extremities.

Roentgenograms of the skull (Fig. 8*A* and *B*) showed pronounced thinning and outward bulging of the anterior two-thirds of the right parietal bone, the posterior half of the right side of the frontal bone and nearly all the squama of the right temporal bone. This thinned area was between 11 and 12 cm. in diameter and its margin was generally distinct and scalloped. There was only slight forward enlargement of the right middle fossa but the posterolateral margin of the right orbit was indistinct. The sella turcica was not remarkable and there was no asymmetry of the sinuses or mastoids.

Operation on August 30, 1950, by Dr. Walker revealed that the thinned bone would transilluminate with the head light. Inferiorly it was so thin that it was easily cut with a pair of scissors. There was thinning of the underlying dura and beneath this there was a large cystic cavity containing clear fluid. The brain was pushed considerably away and covered with an arachnoid-like membrane. This displacement was greatest along the sylvian cleft between the frontal and temporal lobes. The lateral three-fourths of the lesser wing of the sphenoid were plainly visible without any retraction of the brain.

Follow-up examination on January 27, 1951, showed the patient to be completely

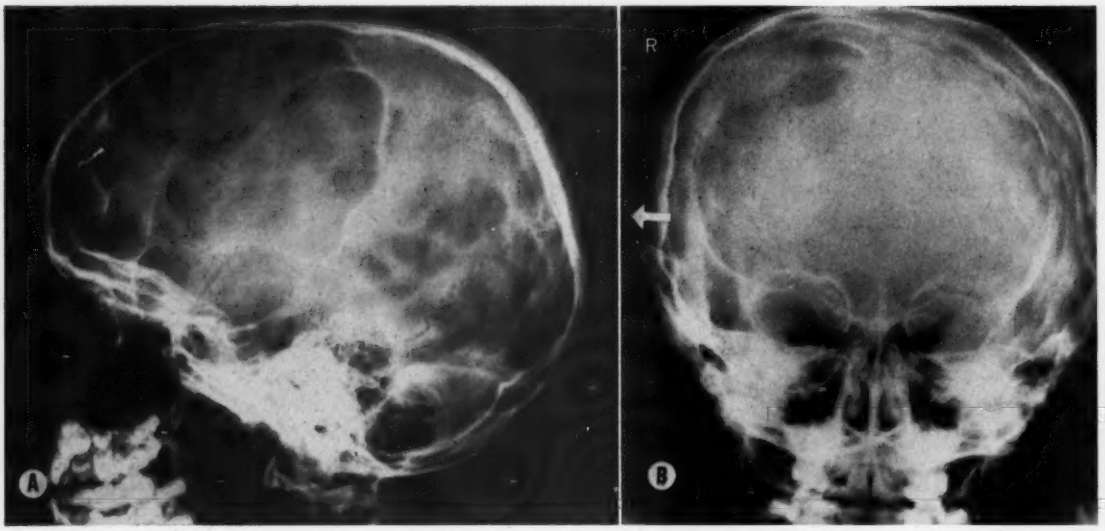


Fig. 8. Case viii. Chronic Subdural Hygroma. Patient, aged six. (*A*) There is pronounced thinning and outward bulging of the anterior two-thirds of the right parietal bone, the posterior half of the right side of the frontal bone and a considerable portion of the squama of the right temporal bone. The margins of this area are generally distinct and scalloped. There is only moderate forward enlargement of the right middle fossa. (*B*) The posterolateral margin of the right orbit is indistinct and the thinning and outward bulging of the right side of the cranium are again shown (arrow).

asymptomatic, and suggested that her personality had brightened considerably following operation.

Comment. In this case there was a very large hygroma and the history and follow-up examination suggest that it caused headaches which were relieved by operation. The hygroma had probably been present much longer than the three months during which the bony prominence had been observed.

B. *Cerebral Agenesis or Atrophy*

Case ix. Y. C. (No. 50-1816), a white male, aged two years, was admitted to the Children's Hospital of Winnipeg on July 18, 1950. This child would not stand alone or walk by himself, although he crawled around and pulled himself up and walked while holding things. He was only able to say a few words. The past history revealed an apparently normal delivery occurring at full term with labor lasting about twelve hours. He had lifted his head up at five months and sat up at nine months. There had been no illnesses or convulsions.

Examination showed him to be a well nourished child who seemed to understand what was spoken to him. The head circumference was 19 inches. It was noted that the left temporal region was quite prominent. There was bilateral primary optic atrophy and there was marked nystagmus to the left. All four extremities were spastic but this was most evident in the left arm. He preferred to use his right arm when playing with objects.

Roentgenograms of the skull (Fig. 9*A*) showed that the left middle fossa was enlarged and that the squama of the left temporal bone and the adjacent portion of the left parietal bone were thinned from within and bulged out decidedly farther laterally than normal. The lesser wing of the sphenoid on the left was considerably higher and more oblique than that on the right side.

Pneumoencephalography (Fig. 9*B* and *C*) revealed marked upward enlargement of portions 2 and 3 (the anterior and middle thirds of the body) of the right lateral ventricle but only moderate enlargement of its remaining portions. No septum pellucidum was visible. The anterior part of the left lateral ventricle corresponded fairly closely with the anterior part of the right. Posterior to this there was a huge cystic cavity. This filled the left middle fossa and the lateral half of the left hemicranium as far backward as the posterior inferior part of the occipi-

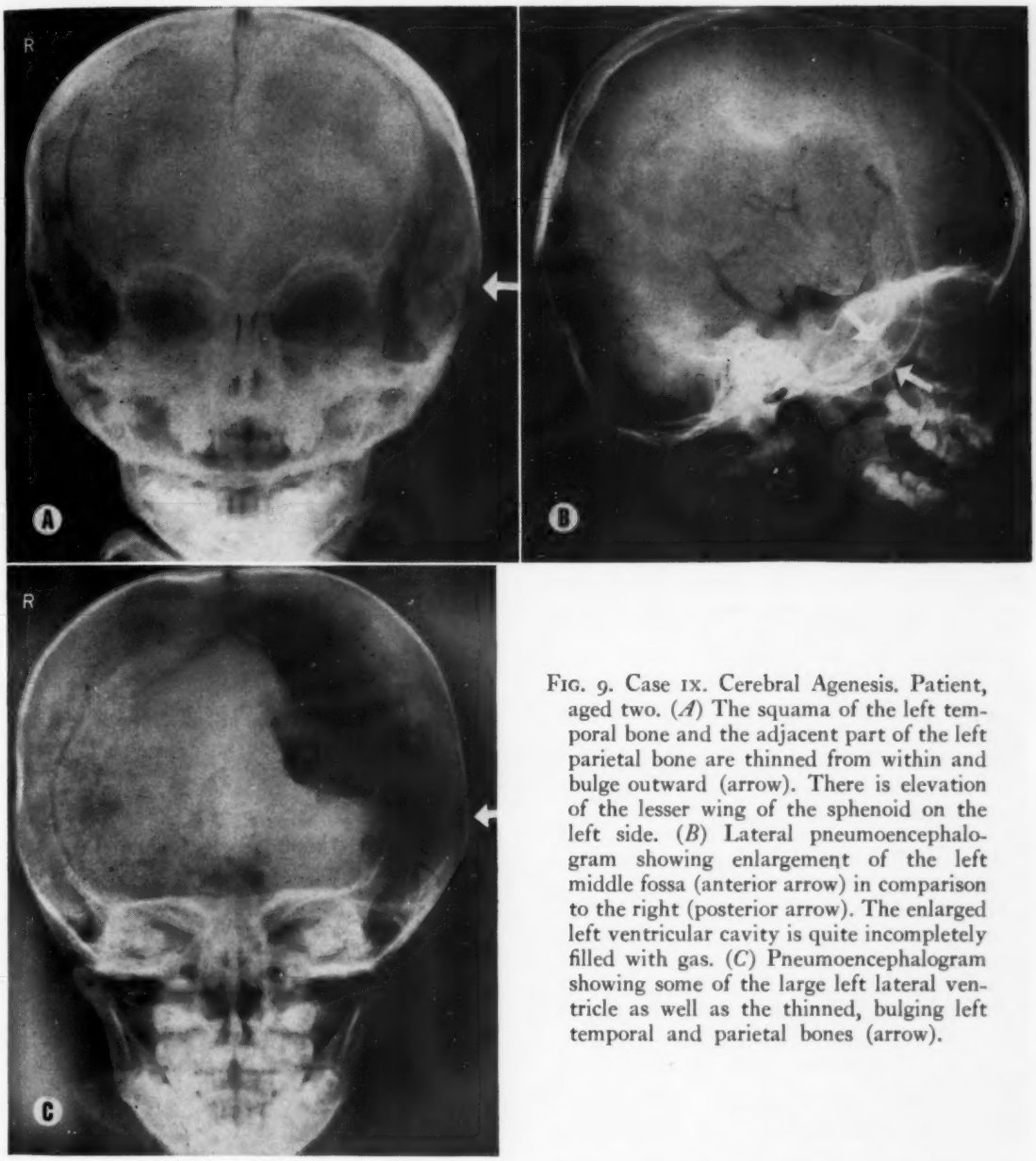


Fig. 9. Case IX. Cerebral Agenesis. Patient, aged two. (*A*) The squama of the left temporal bone and the adjacent part of the left parietal bone are thinned from within and bulge outward (arrow). There is elevation of the lesser wing of the sphenoid on the left side. (*B*) Lateral pneumoencephalogram showing enlargement of the left middle fossa (anterior arrow) in comparison to the right (posterior arrow). The enlarged left ventricular cavity is quite incompletely filled with gas. (*C*) Pneumoencephalogram showing some of the large left lateral ventricle as well as the thinned, bulging left temporal and parietal bones (arrow).

tal lobe. The cavity seemed to represent a hugely dilated ventricle, although the presence of overlying brain substances was not established. No third ventricle was seen. There was a relatively large, but otherwise normal appearing fourth ventricle. The cisterna magna was also large, but the pontine and interpeduncular cisterns were more normal in size. A moderate amount of subarachnoid gas was present over the right cerebral hemisphere.

Left craniotomy by Dr. Hugh Cameron on July 29, 1950, uncovered a thin membrane underlying the dura, separating it from the clear ventricular fluid. The left frontal, temporal and parietal lobes were rudimentary but the choroid plexus was present, extending into the foramen of Monro.

Comment. The bone changes in the plain films of this infant suggested the possibility of a subdural hygroma or hematoma but subsequent investigation ruled out such lesions. It is the only case in this series in which the ventricle was opened and it is

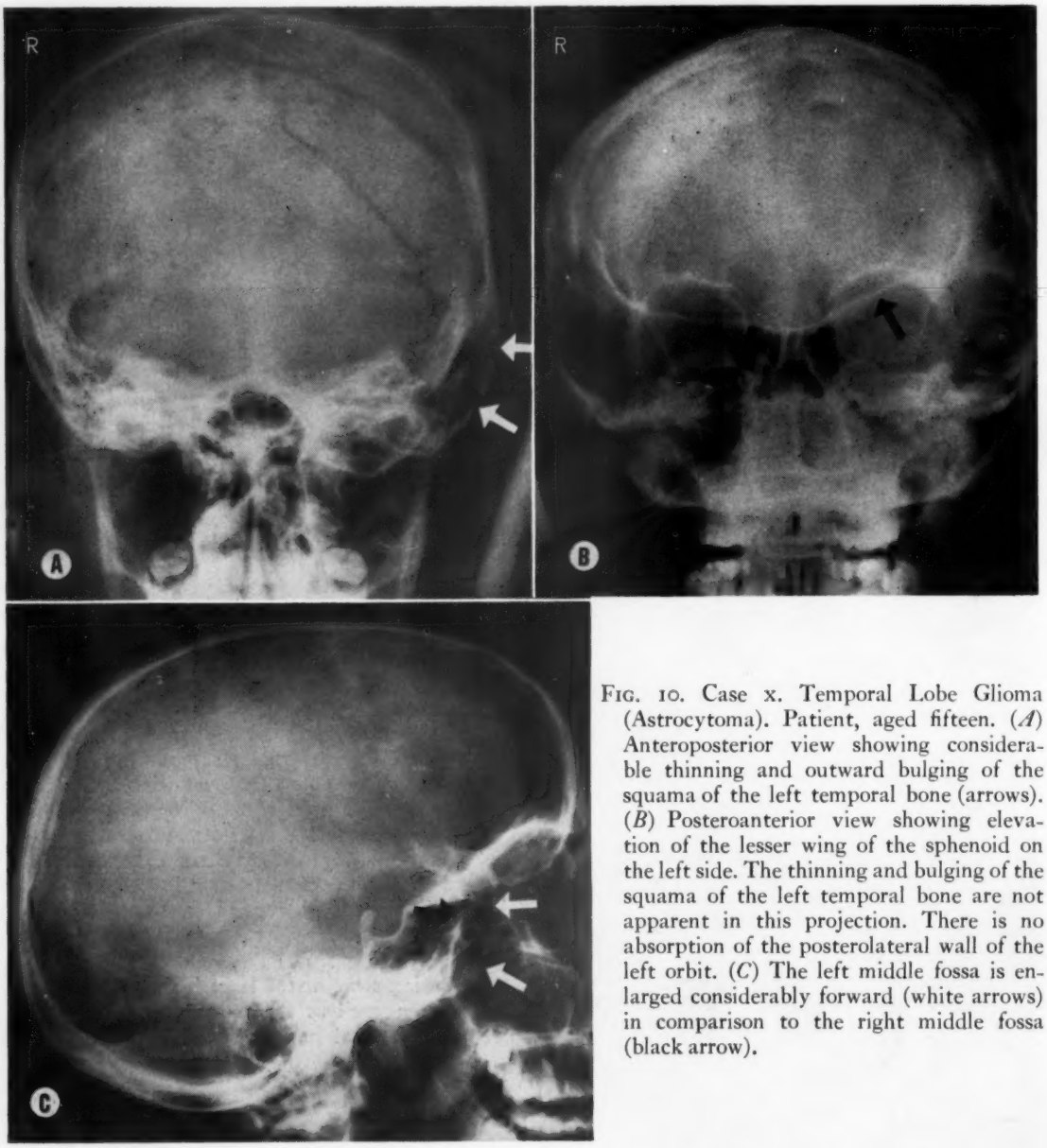


Fig. 10. Case x. Temporal Lobe Glioma (Astrocytoma). Patient, aged fifteen. (*A*) Anteroposterior view showing considerable thinning and outward bulging of the squama of the left temporal bone (arrows). (*B*) Posteroanterior view showing elevation of the lesser wing of the sphenoid on the left side. The thinning and bulging of the squama of the left temporal bone are not apparent in this projection. There is no absorption of the posterolateral wall of the left orbit. (*C*) The left middle fossa is enlarged considerably forward (white arrows) in comparison to the right middle fossa (black arrow).

evident that the thin subdural membrane which was incised represented the ventricular wall situated almost in contact with the inner table of the skull. Ventricular fluid thus exerted localized pressure on the dura and cranium, without the cushioning effect of normal overlying brain. Apparently this gave rise to localized cranial enlargement, similar to that produced by a closed cyst. In retrospect it is evident that operation was completely useless, except to establish a definite diagnosis.

C. *Cerebral Gliomas*

Case x. M. L. (No. 48-3475), a white female, aged fifteen, was admitted to the Children's Hospital of Winnipeg on September 17, 1948. At the age of six years she fell off her bicycle and bruised her forehead. One week later she suffered from a generalized convulsion. There were two other convulsions in the next seven months and then none until she was thirteen. One month before admission she was brought to the Out Patient Department but medication did not control her seizures satisfactorily.

Examination was essentially negative except

for cranial asymmetry, with moderate bulging in the left temporal region.

Roentgenograms of the skull (Fig. 10*A*, *B* and *C*) showed the left middle fossa to be enlarged forward, downward and laterally. The lesser wing of the sphenoid on the left was moderately elevated but the posterolateral wall of the orbit was intact.

Pneumoencephalography failed to visualize the ventricular system. The basal cisterns were well outlined and the roof of the interpeduncular cistern was moderately depressed on the left side. Subarachnoid gas between the anterior portions of the frontal lobes was displaced 5 mm. to the right of the midline. There was an unusual, rather wide subarachnoid channel on the left side well above the middle fossa.

Craniotomy on September 29, 1948, by Dr. Hugh Cameron revealed the dura to be adherent and to bulge moderately in the left temporal fossa. When it was incised a tumor of the left temporal lobe was exposed. Biopsy was taken but a radical removal was not attempted.

The pathologic report by Dr. D. W. Penner was astrocytoma, and Dr. W. V. Cone of Montreal, who was kind enough to review the sections, concurred in this diagnosis.

Comment. It is difficult to assess the significance of the head trauma which occurred nine years previously. The bone changes which were present when the patient finally came under observation were sufficiently definite that craniotomy was carried out without any further attempt at localization when pneumoencephalography failed to visualize the ventricular system. It was evidently a rather slowly growing neoplasm as there has been no apparent change in the symptoms for three years following operation in spite of the fact that radical removal was not carried out. Orley's case, which seems from his illustration to have similar bone changes, is stated to have had a cystic glioma, but no cyst formation was found in our patient.

Case xi. A. W., a white female, aged fifty, was admitted to the Montreal Neurological Institute under the care of Dr. W. V. Cone on October 22, 1935. She complained of intermittent convulsions for fourteen years, double vision and occasional severe headaches for six months and nausea and vomiting with headaches for one month. Examination revealed bilateral papilledema, slight left lower facial

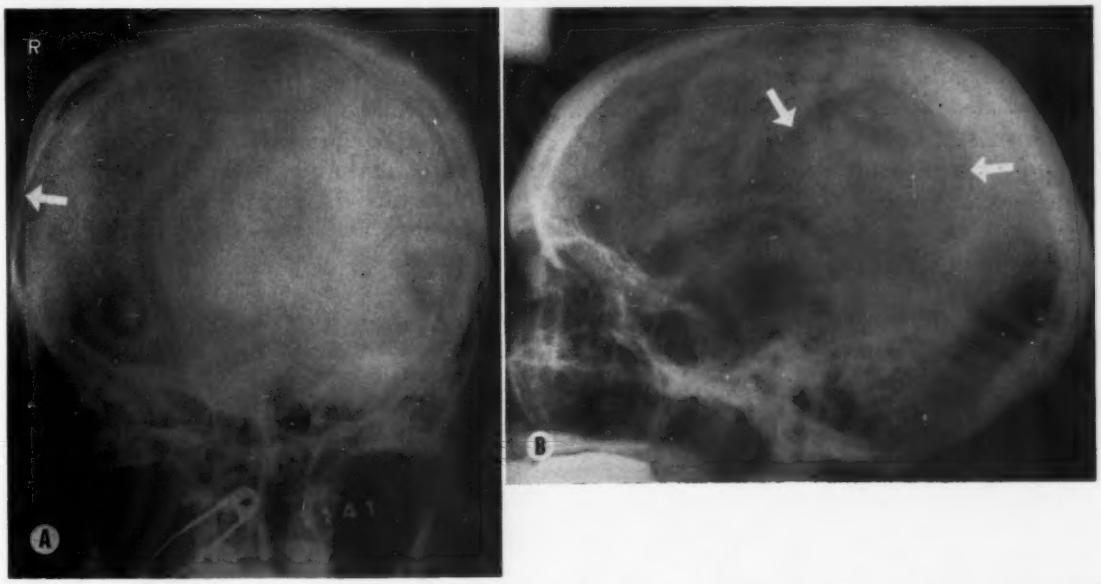


Fig. 11. Case xi. Parietal Lobe Glioma (Oligodendroblastoma). Patient, aged fifty. (*A*) There is marked thinning but only slight outward bulging involving the right parietal bone (arrow). This thinning primarily involves the inner table and the diploë. (*B*) Lateral view showing the thinned area in the right parietal bone (arrows). The posterior clinoids, the dorsum sellae and most of the floor of the sella turcica have been absorbed.

weakness and slight weakness of the left hand and leg.

Plain roentgenograms of the skull (Fig. 11*A* and *B*) showed marked thinning, but only slight outward bulging, involving an area about 7 cm. in diameter in the anterior inferior part of the right parietal bone. This thinning involved primarily the inner table and diploë. The remainder of the cranial vault was quite thick and dense. There was no enlargement of the right middle fossa, but the posterior clinoids and dorsum sellae had disappeared and so had most of the floor of the sella turcica.

Additional roentgenograms made following the aspiration of fluid and its replacement with oxygen showed a large cyst underlying the rarefied area, extending laterally almost to the bone, medially for at least 3.5 cm. and anteriorly to within 3 cm. of the frontal pole. Its posterior limit was at least 3 cm. behind the coronal suture.

Craniotomy by Dr. Cone uncovered a large, pliable, granular, infiltrating tumor, with multiple cysts on the surface. It presented half way between the midline and the sylvian fissure. The surface of the tumor was 6 or 7 cm. in diameter and was not attached to the dura. The final diagnosis was oligodendroblastoma of the right frontoparietal region.

Comment. This is the oldest patient of the series. The bone changes were evidently due to long continued pressure from a cystic glioma but it is interesting to note that there was only slight outward bulging of the involved bone. These findings are in keeping with the statement of Jupe that much cranial bulging is seldom found when the responsible lesion originates after infancy or childhood.

D. *Intracranial Aneurysm*

CASE XII. M. S. (No. A-38908), a white male, aged thirty-two, was admitted to the Winnipeg General Hospital on November 19, 1950. Ten years previously there had been an injury to the right side of the head behind the ear. No effect had been noted for one week, but over the next three weeks he gradually developed paralysis of the right side of the face. Several months after the injury he realized that there was some deafness in the right ear. The left arm had slowly become clumsy and somewhat weak.

Examination revealed complete paralysis of the right seventh nerve and impairment of the right eighth nerve. There were also right cerebellar and left pyramidal signs. The cranium was prominent in the region of the right middle fossa.

Roentgenograms of the skull and base (Fig. 12*A*, *B* and *C*) showed the squama of the right temporal bone to be thinned and to bulge outward. The right middle fossa was enlarged forward moderately and there was elevation of the lesser wing of the sphenoid on the right. The left side of the sella turcica was increased in size and its right side had disappeared. Nearly all of the floor of the right middle fossa had been absorbed and this process extended slightly across the midline in the region of the basisphenoid. There had also been absorption of the apex of the right petrous bone and there was roughening and irregular new bone formation along its superior margin lateral to the internal auditory canal. Narrow, curved linear calcification was present well above the right sphenoid ridge. A moderate sized soft tissue mass bulged into the nasopharynx.

Cerebral angiography (Fig. 12*D*) revealed an aneurysm measuring 4 by 3 by 3 cm. lying in the lateral portion of the right middle fossa. This arose from the internal carotid artery, apparently in the region of the carotid canal in the petrous bone. Beyond this, the extradural cavernous portion of the internal carotid artery was of normal caliber. The middle cerebral branches were considerably elevated.

Pneumoencephalography failed to visualize the ventricular system. The interpeduncular cistern was compressed from above and the apex of the tentorium seemed to be displaced slightly to the left. The right side of the pons was obscured but the left was quite distinct.

Operation was carried out by Dr. Dwight Parkinson on November 23, 1950. After ligating the right internal carotid artery in the neck, a right transfrontal bone flap was turned down. The bone was extremely thin over the aneurysm. The internal carotid was clipped as it came through the dura and the aneurysm exposed in the right middle fossa. It was opened with no bleeding and proved to be about 8 cm. in diameter.

The patient died three days later and at autopsy the presence of an intracranial aneurysm about the size of an orange arising from the right internal carotid artery was confirmed. It had eroded inferiorly through the

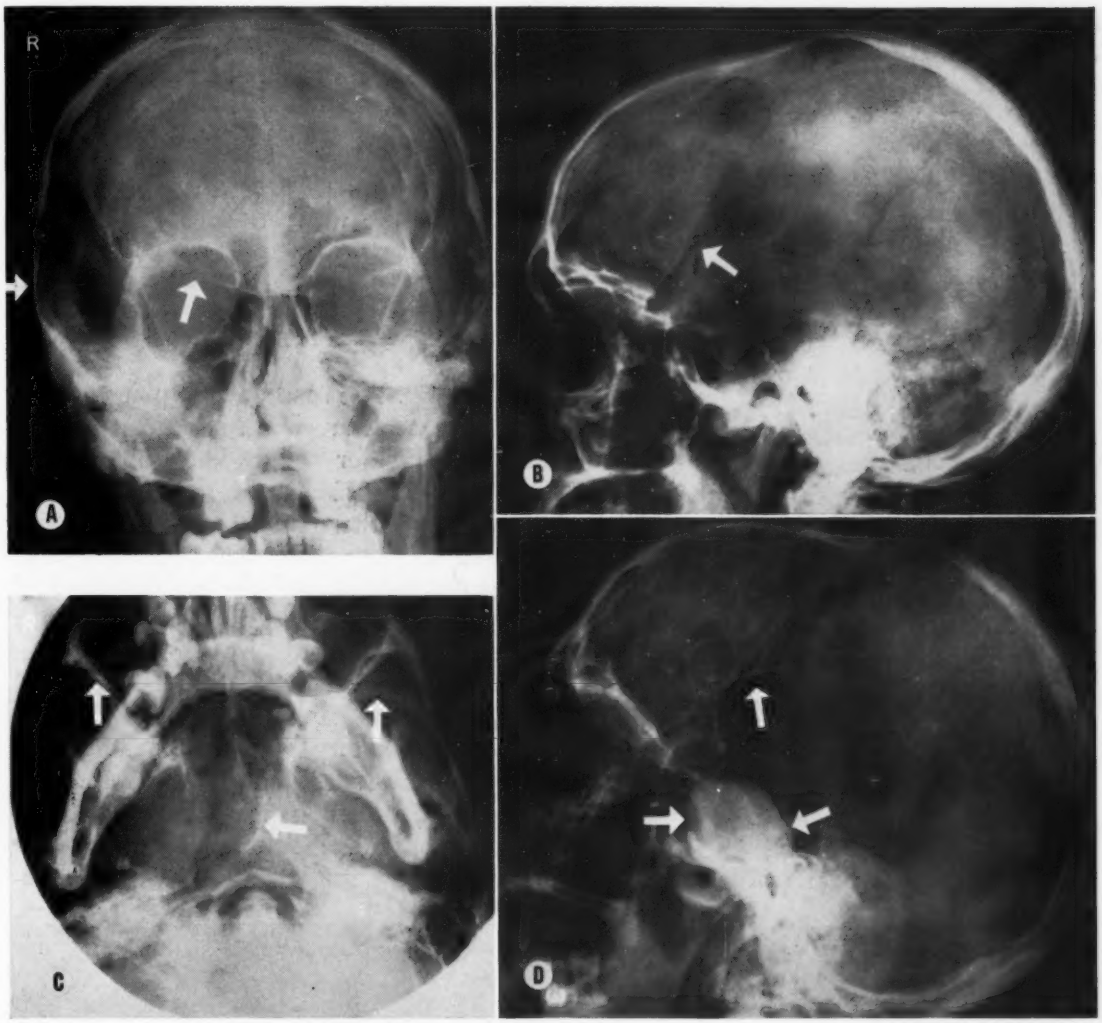


FIG. 12. Case XII. Internal Carotid Aneurysm. Patient, aged, thirty-two. (*A*) The squama of the right temporal bone is thinned and bulges slightly outward (arrow). There is moderate elevation of the lesser wing of the sphenoid on the right (arrow).

(*B*) Calcification is shown in the wall of the aneurysm (arrow). There is enlargement of the left side of the sella turcica and its right side has disappeared.

(*C*) Submentovertical view showing forward enlargement of the right middle fossa (anterior arrow) and erosion of the base of the skull extending slightly across the midline in the basisphenoid (posterior arrow).

(*D*) Cerebral angiogram visualizing some of the large aneurysm in the right middle fossa (lower arrows). Through the anterior part of this aneurysm the cavernous portion of the right internal carotid artery is faintly seen and is of normal caliber. The right middle cerebral vessels are markedly elevated (upper arrow).

floor of the middle fossa, laterally nearly through the temporal bone and medially through the posterior clinoid. The temporal lobe had been displaced upward.

Comment. In this patient the history dates back only to the age of twenty-two years. It may be argued that the aneurysm which accounted for the symptoms and produced the extensive bone changes was congenital and that the trauma caused it to increase in size. The angiogram proved its presence but obviously outlined only a small portion of it. Operation showed the aneurysm to extend laterally in such a

manner that it had caused the cranial thinning and expansion.

E. *Neurofibromatosis*

Case xiii. K. W. (No. A-417), a white female, aged fourteen, was admitted to the Winnipeg General Hospital on January 6, 1948. She complained of marked pulsating proptosis of the right eye. This deformity had been present for six years, but had become much worse in the preceding few months. For one year there had been dull, intermittent frontal headaches. Although at the time no significant family history was elicited, subsequent investigation has disclosed that her father and at least one other relative suffer from neurofibromatosis.

Examination confirmed the presence of marked pulsating exophthalmos on the right.

Roentgenograms of the skull (Fig. 13*A* and *B*) showed the right orbit to be much larger than the left. Its roof was elevated and did not extend nearly as far posteriorly as normal. The greater wing of the sphenoid and the posterolateral wall of the orbit were missing. There was enlargement of the entire right half of the cranium and the right middle fossa bulged forward and outward. The right ethmoid air cells were compressed and the right anterior and posterior clinoids were missing.

Craniotomy by Dr. Oliver Waugh revealed almost complete absence of the right orbital roof. A long, firm tumor, which proved to be a neurofibroma, was removed from the posterior part of the orbit. The orbital roof defect was repaired by a tantalum plate. Following this operation the pulsations of the eye stopped completely but the proptosis increased and enucleation of the eye was performed thirteen days later. In August of the same year an additional neurofibroma was removed from the right orbit. Death occurred some months later but unfortunately autopsy was not obtained.

Comment. The roentgenographic changes in this patient are like those described by LeWald, Pfeiffer and Dyke. The presence of neurofibromas in the right orbit was proved and there was a familial history of neurofibromatosis. Unfortunately, the exact explanation of the enlargement of the middle fossa was not established. In one case operated on by the late Walter E. Dandy, quoted by LeWald, it is stated that the outer surface of the brain was covered with large pools of fluid in the subarachnoid space which when released gave adequate room to elevate the brain without producing trauma. The tip of the temporal lobe was also covered by tremen-

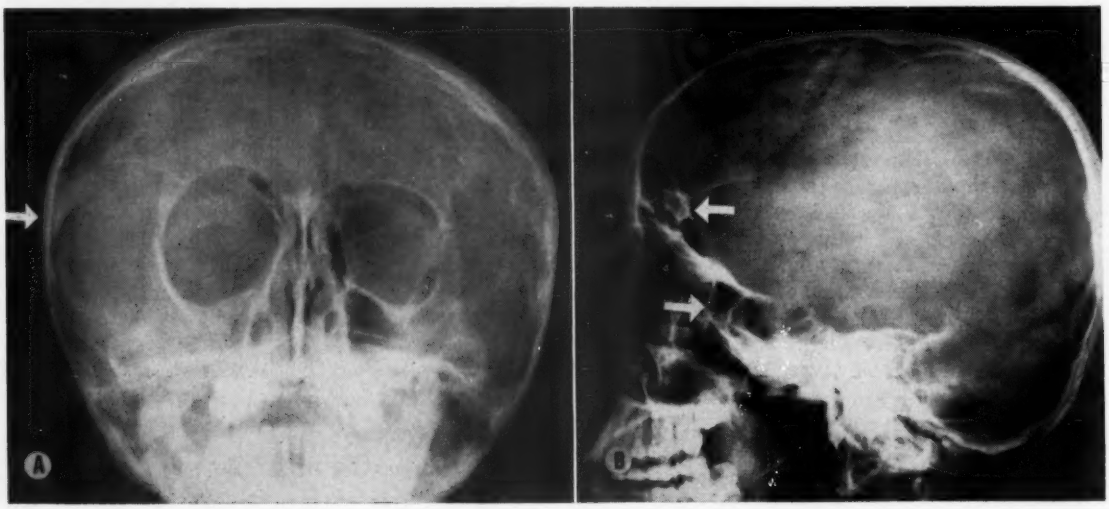


Fig. 13. Case xiii. Neurofibromatosis. Patient, aged fourteen. (*A*) The right orbit is much larger than the left and the right side of the cranium is thinned and enlarged (arrow). The roof of the right orbit is elevated and there is absence of its posterolateral wall and of the greater wing of the sphenoid. Note also the compression of the right ethmoid air cells. (*B*) Most of the roof of the right orbit is missing (upper arrow) and the right middle fossa is enlarged anteriorly (lower arrow). The right anterior and posterior clinoids cannot be identified.

dously dilated subarachnoid spaces with opaque membranes, reaching a maximum depth of about 2.5 cm. A drawing shows enlargement of the middle fossa in this patient.

DISCUSSION

In all these 13 cases there was localized thinning of the skull combined with localized enlargement of the cranial cavity. No prominence of the outer table of the skull was detected in Case VI, but in the remaining cases the outer table bulged, often quite markedly, so that there was an easily palpable hard mass. In Case IV this was the only clinical complaint.

Although various lesions may give rise to localized cranial thinning and enlargement, the most frequent cause in this series was chronic subdural hygroma. Bull considers this lesion to be almost certainly a late result of subdural hematoma. Davidoff and Epstein[4] think that it is closely related to subdural hematoma. They feel that it probably occurs as a result of trauma which produces a tear in the arachnoid, allowing fluid to escape into the potential subdural space. Here it may accumulate outside the cerebrospinal fluid circulation and produce compression of the intracranial contents exactly like a subdural hematoma. No communication between the subdural hygromas and the subarachnoid space or ventricular system was found in any of the 7 cases here reported by the four neurosurgeons who performed craniotomies on them. This is perhaps surprising in view of their clear fluid contents, very similar to cerebrospinal fluid. In 6 instances these cysts had thin, arachnoid-like walls, but in 1 patient (Case II) the lining membrane was heavy.

The roentgenographic findings in the case of cerebral agenesis (Case IX) were quite similar to those produced by chronic subdural hematomas and hygromas and differentiation between agenesis and subdural fluid may well be difficult without recourse to pneumoencephalography. However, diffuse neurological findings such as were present in this infant are improbable with subdural hygromas. The age (two years) is considerably less than that of the youngest patient in whom we have diagnosed a subdural hygroma, but this is not necessarily significant as it seems certain that well developed cranial changes would have been found by this time in many of the hygroma cases had they come under observation sooner. Particularly in Case VIII, who was first seen when she was six years old, there was a striking cranial abnormality which well might have been present four years earlier.

The cranial bulging and roentgenographic changes in Case X indicate that a slowly growing glioma, even though it is not cystic, can produce a rather marked deformity, if it originates reasonably early in life. Signs of this magnitude are not to be expected when the responsible lesion occurs later in life after the skull has ceased to grow.

There is no completely satisfactory explanation for the roentgenographic findings in the case of neurofibromatosis (Case XIII). The orbital deficiency was probably due, at least in part, to the presence of orbital neurofibromas, but the cause of the other cranial abnormalities is uncertain. It is possible that there were, as in Dandy's case, large pools of fluid in the subarachnoid space, but this was not proved. However, this case lends support to the contention of other authors that the etiological factor is very apt to be neurofibromatosis, when there is a pulsating exophthalmos associated with a defect in the orbit.

Localized cranial thinning and enlargement often provide good evidence as to the nature of the responsible lesion. If the bone changes are reasonably marked, there is no clinical evidence of increased intracranial pressure and there are few or no neurological findings, our experience has shown that chronic subdural hygroma is the diagnosis of choice. In most of these cases there are comparatively few clinical complaints other than the cranial deform-

ity and convulsions are rare. The presence of convulsions in Case x should have led us to suspect that the responsible lesion might well be a neoplasm rather than a subdural collection of fluid.

The scalloped margins which are frequently present in chronic subdural hygromas may be confusing, and if it is not recognized that there is actual enlargement of the cranial cavity, this type of lesion may be misdiagnosed as an epidermoid (cholesteatoma). In developmental thinness of the parietal bones the bone changes tend to be bilateral and the thinning involves the outer table and diploë. There is no increase in the internal volume of the skull or in the configuration of the inner table in this condition. Deficiency of the dura, which sometimes results from head injuries either at birth or later in life, may deform the inner table of the skull and may be associated with some outward bulging and even a cranial defect. Under these circumstances the inner table tends to be irregular with the formation of small pits and there may also be new bone formation resembling stalactites. There was erosion through the floor of the middle fossa in Case xii, who had a large intracranial aneurysm, but there was no bony defect in any of the other cases in this series, although it was often so thin that light would shine through it easily and it could be cut readily with scissors.

The occipital bone above the level of the transverse sinuses, on either side of the midline, is often quite thin and it may even appear to bulge outward slightly. This is rarely significant and it is unwise to consider such thinning pathological, if there is no other visible cranial abnormality. But there are exceptions to all rules, as illustrated by the case of a young boy seen a number of years ago, whose films are no longer available. Here there was occipital thinning overlying a greatly enlarged occipital horn, and the mechanism was probably similar to that postulated in Case ix, who had cerebral agenesis.

Even a comparatively minor degree of localized cranial enlargement, particularly when it involves the middle fossa, is usually quite apparent in well positioned stereoscopic lateral roentgenograms of the skull. It is often confirmed by posteroanterior views in which the central ray is directed caudally 20 or 25 degrees in relation to the base line of the skull. The necessity for this degree of angulation has been rightly stressed by Bull who also points out that basal (submentovertical) views are helpful in showing the anterior limits of the middle fossae. Thinning and bulging of the squama of the temporal bone may be much more evident in anteroposterior than in posteroanterior projections (Case x).

SUMMARY

1. Localized thinning and enlargement of the cranium constitute a very significant roentgenologic finding. Although comparatively rare, such changes are probably more frequent than is generally realized.

2. The commonest site for this process to occur is the middle cranial fossa and its immediate vicinity.

3. Most patients in whom such roentgenographic changes are present are children or young adults.

4. Contrary to the experience of others, this series of thirteen cases suggests that localized cranial thinning and bulging are more often produced by chronic subdural hygromas than by chronic subdural hematomas. Cerebral agenesis, slowly growing, superficially situated gliomas, cerebral aneurysms and neurofibromatosis sometimes give rise to similar or identical bone changes.

101 Medical Arts Building
Winnipeg, Canada

I am indebted to Dr. Wilder Penfield for his permission to publish Cases ii and iii, whom I saw in Montreal, and I am very grateful to Dr. Exum Walker for providing me with the clinical findings and roentgenograms of Cases vii and viii. My thanks are also due to Dr. W. V. Cone of Montreal and to Drs. Oliver Waugh, Harry Medovy, Hugh Cameron and Dwight Parkinson of Winnipeg.

ADDENDUM

Since this paper was submitted for publication the author has encountered 2 additional cases of subdural hygroma, both operated upon by Dr. Dwight Parkinson of Winnipeg.

The first was a male, aged fifty-eight, who had suffered from headache, unsteadiness, tinnitus and hallucinations of nauseating odor and taste for three or four months. Plain roentgenograms of the cranium showed moderate forward enlargement of the right middle fossa and elevation of the lesser wing of the sphenoid and of the right anterior clinoid. There was no outward bulging or thinning of the right temporal bone. Pneumoencephalography revealed that the lateral ventricles were shifted about 4 mm. to the left of the midline and that the tip of the right temporal horn did not extend quite as far forward as usual. At operation the entire anterior portion of the right middle fossa was found to be occupied by a thin walled cystic cavity holding 125 cc. of clear fluid. The walls of this cyst could be separated from the inner lining of the dura and also from the arachnoid. The protein content of the fluid ranged from 20 to 25 mg. per cent and the cerebrospinal fluid protein three days before operation was 25 mg. per cent.

The second patient was a boy of thirteen years whose lesion was discovered when roentgenograms were made for a minor head injury. No fracture was found but there was localized thinning and outward bulging of the squama of the left temporal bone. The middle cranial fossa was not enlarged forward. Subsequent questioning of the family revealed that this prominence above the left ear had been noted since early childhood and was of such magnitude that the boy always refused to have a short hair cut because of the revealing disfigurement. Pneumoencephalography showed posterior displacement of the tip of the left temporal horn and a 5 mm. displacement of the lateral and third ventricles to the right. The falx was slightly to the right of the midline, suggesting that the lesion originated very early in life. At operation the temporal squama was found to bulge outward and to be of eggshell thickness. Surprisingly enough, the hygroma which contained over 100 cc. of clear fluid, was situated in front of the thinned squama in the anterior part of the middle fossa. The protein content of the cystic fluid was 15 mg. per cent, the same as the protein content of the cerebrospinal fluid.

REFERENCES

1. Bull, J. W. D. Diagnosis of chronic subdural haematoma in children and adolescents. *Brit. J. Radiol.*, 1949, *22*, 68–80.
2. Dandy, W. E. Treatment of unusual subdural hydroma (external hydrocephalus). *Arch. Surg.*, 1946, *52*, 421–428.
3. Davidoff, L. M., and Dyke, C. G. Relapsing juvenile chronic subdural hematoma. *Bull. Neurol. Inst. New York*, 1938, *7*, 95–111.
4. Davidoff, L. M., and Epstein, B. S. The Abnormal Pneumoencephalogram. Lea & Febiger, Philadelphia, 1950, p. 331.
5. Dyke, C. G. Roentgen-ray diagnosis of diseases of skull and intracranial contests. In: Diagnostic Roentgenology. Ross Golden, Editor. Thomas Nelson & Sons, New York, 1941, Vol. 1, p. 33F.
6. Hardman, J. Asymmetry of skull in relation to subdural collections of fluid. *Brit. J. Radiol.*, 1939, *12*, 455–461.
7. Jupe, M. H. Reaction of bones of skull to intracranial lesions. *Brit. J. Radiol.*, 1938, *11*, 146–164.
8. LeWald, L. T. Congenital absence of superior orbital wall associated with pulsating exophthalmos. Am. J. Roentgenol. & Rad. Therapy, 1933, *30*, 756–764.
9. Orley, A. Neuroradiology. Charles C Thomas, Publisher, Springfield, Ill., 1949, p. 112.
10. Pfeiffer, R. L. Roentgenography of exophphthalmos with notes on roentgen ray in ophthalmology. *Am. J. Ophth.*, 1943, *26*, 816–833.

DISCUSSION*

Dr. Carl List, Grand Rapids, Mich. I am only a neurosurgeon and I feel greatly honored to be called upon to discuss this paper.

Dr. Childe's observations are really unusual. In the vast material of the University of Michigan Hospital, I found only few comparable cases. If we try to analyze the underlying pathophysiologic factors we find, as emphasized by Dr. Childe, that most of these lesions are of long standing; they may have been present since childhood. The moldable skull of young individuals is apparently apt to undergo pressure erosion.

In most of these cases, one finds a large accumulation of fluid immediately beneath the skull. This fluid may be subdural or subarachnoid in location, or a markedly dilated ventricle may extend close to the surface. As a rule, there is no general increase of intracranial pressure

* See also further discussion on page 89.

but the local accumulation of fluid exerts a pulsating pressure. I believe that mainly the pulsation accounts for the bony erosion rather than the factor of pressure. We know that with rising intracranial pressure, the pulsations of the brain diminish. We may now understand why similar cranial changes occur in a large aneurysm which is also a pulsating mass.

I would like to prove my point with a few slides. (Slide) The first case demonstrates compound skull fracture of the cranial vault. Two years later, the roentgenogram (slide) shows an outbending of the skull and widening of the skull defect caused by an underlying pulsating leptomeningeal cyst.

In another observation (slide), the patient sustained a skull fracture in infancy. In the course of fifteen years, a large cranial defect developed. At operation, a leptomeningeal cyst was encountered with a markedly dilated ventricle directly underneath.

In a third case, we see local thinning and bulging of the parietal bone (slide). Pneumography revealed a huge underlying cyst communicating with the displaced ventricles (slide).

In a fourth case, a cystic cerebellar astrocytoma, of many years' duration, produced local erosion of the suboccipital bone.

Finally, I am showing a case of neurofibromatosis with practically complete absence of the roofs of both orbits and of the sphenoid bone. Only the dorsum sellae is preserved whereas all structures in front of it are missing (slide). Cases of this type must probably be considered developmental rather than be caused by local pulsating pressure.

Vol. 70, No. 1

OCCIPITALIZATION OF THE ATLAS*

By D. L. McRAE, M.D.,† *and* A. S. BARNUM, M.D.‡
From the Montreal Neurological Institute
MONTREAL, P. Q., CANADA

FOR many years anomalies in the region of the foramen magnum were of interest mainly to anatomists. In the latter half of the 19th century they began to be described in the pathological literature, and in 1911 Schüller reported a case of basilar invagination diagnosed during life. Since that time reports of small series of cases by Ebenius, Chamberlain, Peyton and Peterson, Schatzki, and finally List, have appeared in the English literature. We have been fortunate enough to see a large number of cases, sufficient to allow separation of the various bony anomalies into groups for analysis. This report deals with one specific type of congenital bony deformity at the foramen magnum. The lesion has been called occipitalization of the atlas or assimilation of the atlas to the occipital bone. We present 25 cases.

MORPHOLOGY

To sustain a diagnosis of assimilation of the atlas one must show some degree of bony union between the skull and the atlas. Lack of movement between the skull and atlas is not an absolute criterion. We have seen several patients in whom movement of the skull on the atlas could not be shown on the roentgenogram (Fig. 1). In this case a fusion of the atlas and axis was carried out. Films made six months later showed definite movement at the atlanto-occipital joint, proving that there had been no bony union. In others, slight movement was shown at operation.

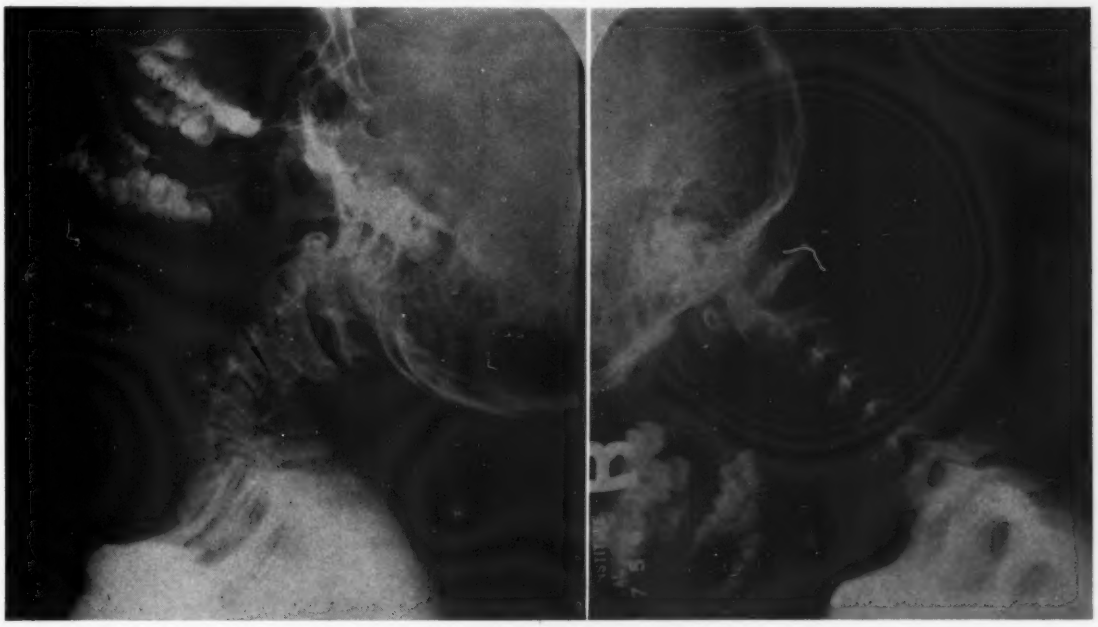


FIG. 1. Lateral films of the neck of a ten year old boy showing no movement of the skull on the atlas. This is not a case of assimilation of the atlas.

* Presented at the Fifty-second Annual Meeting, American Roengten Ray Society, Washington, D. C., Sept. 25–28, 1951.
† Radiologist, Montreal Neurological Institute.
‡ Assistant Registrar, Montreal Neurological Institute.

TABLE I

Case No.	1	2	3	4	5	6	7	8*	9	10	11
Initials	A.A.	C.B.	G.B.	L.B.	N.B.	F.B.	T.C.	A.G.	C.G.	A.H.	W.J.
Sex	M	F	F	F	M	M	M	M	M	M	M
Age in years	44	27	44	26	4	22	39	37	23	50	14
Neurological signs	yes	yes	yes	no	no	yes	no	yes	no	yes	yes
Arnold-Chiari	yes	no	no	—	—	no	—	—	—	—	—
Dural band	no	yes	no	—	—	yes	—	—	—	—	—
Basal angle	136	140	140	138	130	135	133	140	135	120	128
Basilar invagination	no	sl	no	no	sl	no	sl	sl	sl	sl	no
Clivus	cv	cc	cc	cc	cc	cc	cc	cv	cc	cc	cc
Petrous tips	up	H	H	H	H	H	H	H	up	down	H
Atlanto-occipital joint R	no	no	no	no	no	no	5 mm	no	no	no	no
Atlanto-occipital joint L	no	no	no	no	no	no	no	no	no	no	no
Posterior fringe	L	L	S	L	L	L	S	L	L	S	S
Posterior edge of foramen	A	A	—	—	—	A	—	S	—	—	—
Spina bifida of atlas	no	no	L	L	no	no	L	no	no	no	L
Posterior arch to foramen	F	F	F/3 mm	F	0 mm	F	F	F	F	F	0 mm
Anterior arch to foramen	F	F	F	F 2 mm	F 1 mm	F	F 2 mm	F	F 2 mm	F 4 mm	F
Transverse processes R	F D	F N	F D	S N	—	S N	S N	P	P	—	P
Transverse processes L	F D	F D	S N	S D	—	S D	P	P	F N	—	F N
Atlanto-axial joints	◿◺	◿◺	—◺	◿—	?	◿◺	◿◺	—◺	—◺	?	◿—
	0 mm	0 mm	3 mm	1 mm	—	2 mm	0 mm	2 mm	2 mm	—	1 mm
Dens height/A.P. diameter	16/14	16/14	14/14	13/11	10/8	15/15	15/11	20/14	11/11	20/14	9/9
Angle of dens	205	170	180	165	200	180	170	180	190	180	180
Dens above C. line	10	10	4	7	−5	10	11	24	11	5	6
Dens above foramen	1	2	3	−4	−3	7	5	24	6	7	4
Dens to anterior arch	8	12	2	4	3	8	2	2	4	10	3
Dens to posterior edge	22	14	28	25	23	13	32	30	20	19	25
Fusion C_2–C_3	yes	yes	no	yes	yes	no	no	no	yes	no	yes
Other fusions	no	no	no	no	no	no	no	no	no	no	no
Cervical	7	7	7	7	7	7	7	7	7	7	7
Thoracic	12	—	12	12	12	12	—	12	—	—	—
Lumbar	—	—	—	—	—	5	—	5	—	5	—
Sacral	—	—	—	—	—	5	—	5	—	5	—
Coccygeal	—	—	—	—	—	4	—	4	—	3	—

In all of our cases of assimilation there seemed to be bony continuity between the anterior arch of the atlas and the anterior lip of the foramen magnum (Fig. 2, 4 and 5). In most cases the cortex of the anterior arch was continuous with that of the basi-occiput and in some the medulla of the basi-occiput was continuous with that of the anterior arch. In these there was no anterior atlanto-occipital interval. In 2 cases laminagrams showed what seemed to be a thin plate of bone 1 or 2 mm. in length passing in a coronal plane from the anterior lip of the foramen magnum down to the upper edge of the anterior arch of the atlas (Fig. 2). In the light of the anatomical findings of Harrower and of Gladstone and Wakeley it is likely that the anterior atlanto-occipital interval, if present, is only partly closed by spicules of bone. These spicules are parallel to the plane of travel of the laminagraph, and may appear as a plate. In another 5 cases in which laminagrams were made it was possible to show cortical or medullary continuity between the anterior lip of the foramen and the anterior arch. In 12 of the cases in which laminagrams were not done this region was clearly visualized on lateral films and bony continuity could be seen, except possibly in Case 5, a boy of four years (Fig. 9). In the remaining cases there was overlap of the mastoid processes, or some other structure but over-exposed lateral films gave fair visualization and showed that the anterior arch was at least in contact with the basi-occiput. The largest anterior atlanto-occipital interval was 6 mm. The anterior arch of the atlas in lateral view was usually round or oval in shape. A well formed facet on its posterior surface was never shown, however,

Atlanto-occipital joint spaces were demonstrated in 3 cases. In Case 7 a joint space was seen on the right 5 mm. below the occipital squama, and on the right the transverse process of the atlas was average in length and not fused to the base of the

TABLE I

12	13	14	15	16†	17	18	19	20	21	22	23	24	25
F.K.	A.L.	A.L.	A.L.	G.L.	M.L.	R.L.	C.M.	J.M.	S.M.	L.O.	R.O.	F.P.	J.T.
M	M	F	M	M	M	M	M	M	M	M	M	M	F
49	36	46	22	48	32	40	46	29	62	51	24	24	15
yes	no	yes	yes	yes	yes	yes	no	yes	no	no	yes	no	yes
no	—	no	no	no	—	no	—	no	—	—	yes	—	yes
yes	—	yes	no	no	—	no	—	no	—	—	no	—	no
136	138	145	138	128	140	130	130	140	150	140	130	145	145
sl	sl	no	no	sl	no	sl	no	sl	no	sl	no	sl	sl
cv	cc	cc	cc	cc	cc	st	st	st	st	st	cc	cc	cv
H	—	H	—	H	—	H	H	up	down	H	H	H	up
no	no	no	no	no	no	no	no	no	no	no	no	4 mm	no
no	no	no	no	no	no	no	no	no	no	2 mm	no	?3 mm	no
no	L	L	S	L	S	no	L	L	S	L	L	no	L
A	—	—	—	—	—	—	—	S	A	—	—	—	—
L	no	no	no	no	no	L	no	no	S	L	no	no	no
0 mm	0 mm	F	F	F	F	—	F	F	F/7 mm	0/5 mm	F	2 mm	F
F	F	F 1 mm	F	F	F 3 mm	F 1 mm	F 2 mm	F	F 2 mm	F 1 mm	F 2 mm	F	F 1 mm
P	—	S N	—	—	—	F D	F D	—	S N	F D	F D	S N	F D
F D	—	F D	—	—	—	S N	F D	—	S N	S N	F D	F D	F N
—\	—\	/—	—\	/—	——	/\	/\	/\	—\	—\	/—	/—	—\
3 mm	1 mm	4 mm	1 mm	0 mm	2 mm	2 mm	1 mm	2 mm	1 mm	5 mm	1 mm	2 mm	6 mm
15/10	14/13	10/14	15/13	10/16	12/16	12/16	10/12	14/14	11/13	16/11	10/11	16/14	10/11
180	190	205	180	180	190	190	180	180	165	200	180	180	150
14	8	8	6	10	5	4	9	14	7	16	7	15	3
10	7	2	10	3	0	0	−1	10	−3	6	−3	3	0
6	1	4	9	5	3	9	2	5	1	2	1	2	8
18	23	19	15	17	27	19	19	17	32	32	23	30	20
yes	no	no	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	yes
no	C_{4-5}	no	no	no	no	no	C6–7	no	no	no	T1–2	no	no
7	7	7	8	7	8	7?	8	7	7	7	7	7	7
—	—	—	12	—	—	14?	12	12	12	12	—	—	12
—	—	—	5	—	—	5	5	5	5	—	—	—	—
—	—	—	5	—	—	5	5	5	5	—	—	—	—
—	—	—	3	—	—	4	3	4	4	—	—	—	—

* Courtesy of Dr. G. T. Adams, Queen Mary Veterans Hospital, Montreal, Canada.
† Courtesy of Dr. Norman Brown, Montreal General Hospital, Montreal, Canada.

KEY TO TABLE I

Arnold-Chiari: Yes = either the Arnold-Chiari malformation or herniation of the cerebellar tonsils downward through the foramen magnum (Arnold's defect) was found at operation or autopsy. No = neither was found. —implies no operation or autopsy.

Dural band: "Yes" implies that an abnormal inward projection of dura was found at the foramen magnum at operation or autopsy. No—it was absent. —implies no operation or autopsy.

Basal angle: See text.

Basilar invagination: See text. No = none. Sl = slight.

Clivus: See text. cc = concave; cv = convex; st = straight.

Petrous tips: See text. Up = the tip is higher than the tegmen tympani; down = lower; H = horizontal.

Atlanto-occipital joint: No = absent. If present a measurement is given showing the distance of the joint space below the base of the posterior fossa of the skull.

Posterior fringe: This refers to a posterior bony fringe hanging down from the occipital part of the foramen magnum. No = no fringe; L = large; S = small.

Posterior edge of foramen: This refers to the occipital part of the foramen magnum. A = the posterior edge is asymmetrical; S = symmetrical; — = not seen on the films.

Spina bifida of atlas: This refers to the atlas, either assimilated or not. If one-half of the posterior arch is fused to the occiput but the other half is free it was scored as a spina bifida. L = large or wide; S = small or narrow; No = no spina bifida.

Posterior arch to foramen: This indicates the distance in mm. between the posterior lip of the foramen magnum and the posterior arch of the atlas. F = fused or bony continuity; 0 mm. = contact without fusion; 2 mm. = unfused and 2 mm. below the occipital. If one side of the posterior arch is fused to the occiput and the other half not it is indicated by F/3 mm.

Anterior arch to foramen: This indicates the relationship of the anterior arch of the assimilated atlas to the anterior lip of the foramen magnum. F = bony continuity F 2 mm = bony continuity by a plate 2 mm. in length bridging the anterior atlanto-occipital interval.

Transverse processes: F = fused to occipital; S = separate or not fused to occipital; N = normal in shape and size D = abnormal in shape and/or size P = paramastoid process.

Atlanto-axial joints: The horizontal and oblique lines show the relative angles and heights of the joint surfaces, the right joint being on the reader's left side. The figure shows the distances between them.

Dens: Height/A.P. diameter. See text.

Angle of dens: See text.

Dens above C. line: Distance in mm. of tip of dens above Chamberlain's line.

Dens above foramen: Distance in mm. of tip of dens above foramen magnum line.

Dens to anterior arch: Distance in mm. between the dens and the assimilated anterior arch.

Dens to posterior edge: Distance in mm. between the dens and the closest of the following bony points: posterior lip of the foramen magnum, posterior fringe, or the posterior arch of the atlas.

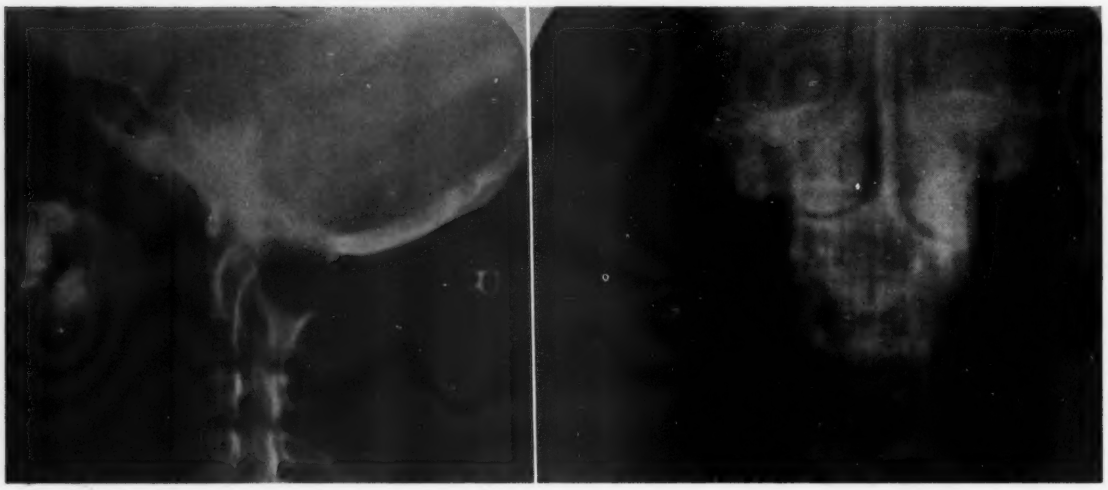


FIG. 2. Case 25. Anteroposterior and lateral laminagrams showing the anterior atlanto-occipital interval bridged by bone, a backward bending odontoid process, fusion of C2 and C3, asymmetrical atlanto-axial joints and absence of atlanto-occipital joints.

skull. The right half of the posterior arch of the atlas was not fused to either the skull or the left half of the posterior arch. The atlanto-axial joints were at the same level. In Case 22 an atlanto-occipital joint space was seen on the left 2 mm. below the level of the floor of the posterior fossa. The left half of the posterior arch of C1 was separate from the skull as was the left transverse process. The right half of the posterior arch and right transverse process were fused to the skull. The left atlanto-axial joint was 5 mm. lower than the right. In Case 24 a right atlanto-occipital joint space was seen 4 mm. below the the base of the posterior fossa and there was some suggestion of a similar space on the left side at a slightly higher level. The right transverse process was not fused to the skull but the left was. In all other cases it was not possible to show atlanto-occipital joint spaces by any method of examination. The bony masses representing the fused occipital condyles and lateral masses of the atlas were often asymmetrical (Fig. 2 and 11). In 11 of the 23 cases in which the inferior facets of the assimilated atlas were clearly seen the right facet lay from 1 to 4 mm. below the left. In 8 cases the left facet lay from 1 to 6 mm. below the right. In 4 cases the facets were at the same level. Usually the high facet had a horizontal or nearly horizontal articular surface, while the low facet had an oblique surface as seen in the open-mouth view, the lateral edge being lower than the medial edge. Sometimes their asymmetry seemed due to the occipital condyles, or lateral masses, being of different size; other cases were due to different degrees of assimilation of the right and left sides of the atlas, and others were due to combinations of these two factors. In no case did the joint between the assimilated atlas and the axis resemble an atlanto-occipital joint. In 7 of the 12

FIG. 3. Case 25. Oxygen myelogram showing posterior displacement of the spinal cord by the backward tilted odontoid. There is no tonsillar herniation.

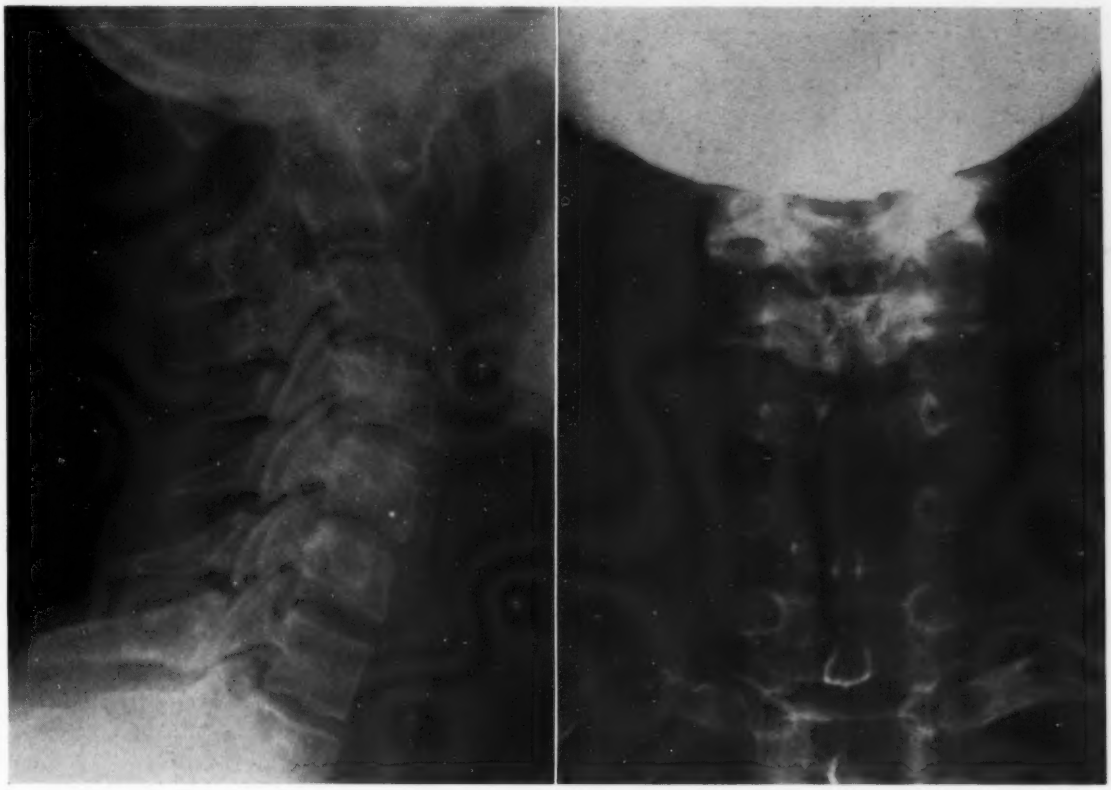


Fig. 4. Case 6. Anteroposterior and lateral views. Note continuity of both cortex and medulla between the basi-occiput and the anterior arch of the atlas.

patients who had bending films the assimilated atlas rocked on the axis (Fig. 13). This nodding movement is said to be a function of joints with curved surfaces such as the normal atlanto-occipital joint, but this does not always hold true (Fig. 10 and 14).

The transverse processes of the atlas might be normal, but this was rare. Even when free from the occipital the transverse process would often have either the costal element or lateral half missing so that a complete arterial foramen was not present. Even when fused to the occipital (most often at the tip of the transverse process) the transverse process might look almost normal. In 5 cases a distinct paramastoid process was present (Fig. 16), not attached to the atlas and there was no transverse process on the atlas. The submentovertical view gave the best idea of the shape of the transverse process but the over-exposed anteroposterior film of the skull showed fusion, or nonfusion, of the transverse process and demonstrated a separate paramastoid process best. In at least 11 cases, one or both transverse processes were attached to both the occipital and the lateral mass of the atlas.

Some trace of the posterior arch of the atlas was present in all but 2 cases. Usually it was a bony fringe on the posterior edge of the foramen magnum (Fig. 4) which was directed downward and inward producing more or less constriction of the spinal canal and in 1 case grooving the back of the spinal cord. This fringe became smaller as it passed laterally and forward around the margins of the foramen magnum and often disappeared completely before the lateral mass was reached. It might persist as a rolled edge for the lateral margin of the foramen magnum. Occasionally only the right or left half of this fringe was present (Fig. 7). In these cases the opposite half of

TABLE II

Case No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Initials	A.A.	C.B.	G.B.	L.B.	N.B.	F.B.	T.C.	A.G.	C.G.	A.H.	W.J.	F.K.	A.L.	A.L.	A.L.	G.L.	M.L.	R.L.	C.McK.	J.M.	S.M.	L.O'H.	R.O.	F.P.	J.T.
Sex	M	F	F	F	M	M	M	M	M	M	M	M	M	F	M	M	M	M	M	M	M	M	M	M	F
Age in years	44	27	44	26	4	22	39	37	23	50	14	49	36	46	22	48	32	40	46	29	62	51	24	24	15
Symptoms*	+	+	+	o	o	+	+	+	o	+	+	+	+	+	+	+	+	+	o	+	o	o	+	o	+
Signs†	+	+	+	o	o	+	o	+	o	+	+	+	o	+	+	+	+	+	o	+	o	o	+	o	+
Age at onset of symptoms	43	25	39	—	—	21	39	30	—	21	13	49	36	41	21	45	27	32	—	22	—	—	24	—	8
Other cervical abnormalities	+	+	o	+	+	+	o	+	+	+	+	+	+	+	+	+	+	+	o	+	+	+	+	+	+
Dural band	o	+	o	—	—	+	—	—	—	—	—	+	—	+	o	o	—	o	—	o	—	—	+	—	+
Tonsils of cerebellum down	+	+	o	—	—	+	—	—	—	—	—	o	—	+	o	o	—	o	—	o	—	—	+	—	+
Arnold-Chairi	+	o	o	—	—	o	—	—	—	—	—	o	—	o	o	o	—	o	—	o	—	—	+	—	+
Platybasia	o	o	o	o	—	o	o	o	o	o	o	o	o	+	o	o	o	o	o	o	+	o	o	+	+
Intervertebral disc disease	o	o	+	o	—	o	o	o	o	+	o	o	o	o	o	o	o	+	o	o	+	o	o	o	+
Odontoid back	+	+	o	+	o	+	o	o	+	+	o	+	+	+	o	+	o	+	o	+	o	+	o	+	o
Odontoid up above foramen magnum line	+	+	+	o	o	+	+	+	+	+	+	+	+	+	+	+	o	o	o	+	o	+	o	+	o
Fusion C_{2-3}	+	+	o	+	+	o	o	o	+	o	+	+	o	o	+	+	+	+	+	+	o	+	+	+	+
Cerebrospinal fluid block	o	+	o	+	o	+	o	o	o	o	o	+	o	+	o	o	+	o	o	+	o	+	+	+	+
Previous misdiagnosis	+	+	o	o	o	o	o	o	o	o	o	+	o	o	o	+	+	o	o	+	o	o	+	o	+
Trauma before symptoms	+	o	+	o	o	o	+	o	o	+	+	+	o	+	o	o	+	+	o	+	+	+	+	+	o
Associated disease	+	o	+	+	+	o	o	o	+	+	+	o	o	o	o	o	+	o	+	+	+	+	+	+	o
Symptoms:																									
Headache	+	o	+	o	o	o	+	o	+	+	+	+	+	o	o	o	o	o	o	+	o	+	+	o	o
Dizziness	o	o	+	+	o	o	o	+	o		o	+	o	o	o	o	o	o	o	o	o	o	+	o	+
Neck Pain	o	o	+	o	o	+	o	o	o	o	o	+	o	+	o	o	o	o	o	o	o	o	+	o	+
Weakness or ataxia	+	+	+	o	o	+	o	+	o	o	+	+	+	+	o	+	+	+	o	+	o	o	+	o	+
upper extremities	+	+	+	o	o	o	o	+	o	o	+	+	+	o	o	o	+	+	o	+	o	o	o	o	+
lower extremities	+	+	o	o	o	+	o	+	o	o	+	+	+	+	o	+	+	+	o	+	o	o	+	o	+
bulbar	+	o	o	o	o	+	o	o	o	o	+	+	o	+	o	o	o	o	o	o	o	o	o	o	o
Visual	+	+	o	+	o	+	o	o	o	o	+	+	o	o	o	o	o	o	o	o	o	o	+	o	o
Pain and/or numbness	o	o	+	+	o	+	o	o	o	+	o	+	o	o	+	+	+	+	o	o	+	o	o	o	o
upper extremities	o	o	+	+	o	+	o	o	o	+	o	+	o	o	+	+	+	+	o	o	+	o	o	o	o
lower extremities	o	o	o	+	o	o	o	o	o	o	o	+	o	o	o	o	o	+	o	o	o	o	o	o	o
Ear symptoms	o	o	o	o	o	o	o	o	o	+	o	o	+	o	o	+	o	o	o	o	o	o	o	o	o
Sympathetic	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	+	o	o	o	o	o	o	o	+
Urinary	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	+	o	o	o	o	o	o	o	o
Signs:																									
Nystagmus	+	+	o	o	o	+	o	+	o	o	+	o	o	+	+	o	o	o	o	o	o	o	+	o	o
Bulbar	+	o	o	+	o	o	o	o	o	o	+	o	o	+	o	o	+	o	o	o	o	o	+	o	o
Long tract signs (weakness, reflexes)																									
upper extremities	+	+	o	o	o	+	o	+	o	+	+	+	o	+	+	+	+	+	o	+	+	o	+	o	o
lower extremities	+	+	o	o	o	+	o	+	o	+	+	+	o	+	+	+	+	+	o	+	o	o	+	o	o
Spasticity	+	+	o	o	o	o	o	o	o	o	o	o	o	o	+	+	o	+	o	o	o	o	+	o	o
Ataxia																									
upper extremities	o	o	o	o	o	+	o	+	o	o	+	+	o	+	+	+	o	o	o	o	o	o	o	o	o
lower extremities	+	o	o	+	o	+	o	+	o	o	+	+	o	o	o	o	o	o	o	o	o	o	o	o	o
Head tilt	o	o	o	+	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Pain on movement of neck	o	o	o	o	o	o	o	o	o	+	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o
Posterior column (touch, vibr., position)																									
upper extremities	o	o	o	o	o	o	o	o	o	o	o	o	o	o	+	+	o	+	o	+	o	o	o	o	o
lower extremities	+	+	o	o	o	o	o	+	o	o	o	+	o	o	+	+	o	+	o	+	o	o	o	o	o
2-point and asterognosis																									
upper extremities	o	o	o	o	o	o	o	o	o	o	o	+	o	o	+	o	o	+	o	+	o	o	+	o	o
lower extremities	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	+	o	o	+	o	o
Sensation impairment (pinprick)																									
upper extremities	o	o	o	o	o	+	o	o	o	+	o	+	o	+	+	+	+	o	o	o	o	o	o	o	o
lower extremities	o	o	o	o	o	+	o	o	o	o	o	+	o	o	o	+	+	o	o	o	o	o	+	o	o
Visual	o	+	o	+	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	+	o	o
Bladder	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	o
Sympathetic	o	o	o	o	o	+	o	+	o	o	o	o	o	o	o	o	o	o	o	o	+	o	o	o	o

+ = absent.
o = absent.
— = not recorded or uncertain
* Symptoms thought to be referable to cervical abnormality.
† Signs thought to be referable to cervical abnormality rather than to any associated disease.

the posterior arch might be present and not attached to the occiput or might be absent. Rarely there was a right and left rolled edge but no fringe on the posterior margin (spina bifida posterior of the assimilated atlas). Two cases showed an unfused rudiment of one side of the posterior arch and no trace of the rest of the arch. A sickle-shaped band of dura was found at the posterior edge of the bony foramen magnum in 4 of the 12 cases which came to operation, but we could not correlate its presence with the presence or absence of the bony fringe.

Except for the assimilated vertebra the skull was surprisingly normal. The basal angle was usually normal. Because of difficulty in following Schüller's original definition of basal angle (the angle subtended by the planes of the clivus and planum sphenoidale) we have used lines drawn from the tuberculum sellae to the nasofrontal suture and to the anterior lip of the foramen magnum to find the basal angle. We feel that the upper limit of normal is 140° and use the word platybasia to denote a basal angle of 145° or more. Twenty-one cases had no platybasia, the basal angles varying from 120° to 140°. Two symptomless cases had basal angles of 145° and 150° and 2 cases with symptoms had basal angles of 145°. This surprised us as we used to believe that platybasia frequently accompanied occipitalization of the atlas and played a part in the production of symptoms. Apparently it does not. We assumed that platybasia and assimilation were found together because in many of the cases of platybasia the atlas was in contact with the occipital and seemed assimilated. Critical review of the operative and autopsy findings as well as laminagraphic and bending film examinations has forced us to revise our ideas. Anteroposterior laminagrams or lateral laminagrams in flexion and extension will show atlanto-occipital joint spaces or atlanto-occipital movement in nearly all cases of platybasia.

We have seen skulls with normal basal angles in which the lateral margins of the foramen magnum were invaginated and

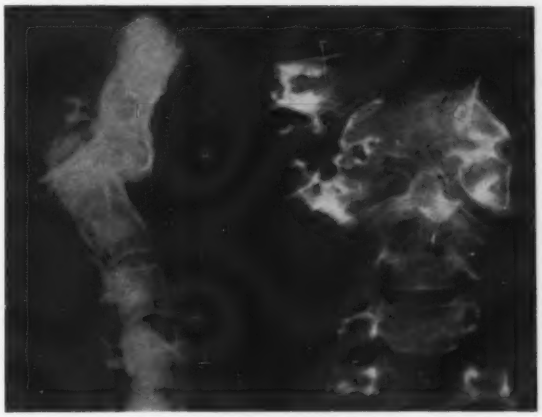


Fig. 5. Case 6. Anteroposterior and lateral views of the excised skull base and cervical vertebral bodies.

the occipital condyles had risen. We have come to call this basilar impression or basilar invagination. We do not use platybasia and basilar impression as synonyms even though the two conditions often coexist. To measure basilar impression, we join the anterior and posterior lips of the foramen magnum (not the assimilated anterior and posterior arches) by a straight line. In the true lateral view the occipital squama on each side of the foramen magnum is seen as a thin dense plate of bone convex downward lying below this line, and the occipital condyles may sometimes be seen through the shadows of the mastoid tips about 10 mm. below this line. If the line of the occipital squama is convex upward or if it lies above the line of the foramen magnum or if the occipital condyles lie on or above the line of the foramen magnum, we say that basilar impression is present. Ten cases had no basilar impression. Fifteen cases had slight impression. The patient with the basal angle of 150° had no basilar impression as did one of those with an angle of 145°. Seven of those without basilar invagination had neurological signs. It is safe to say that the slight platybasia and the slight basilar invagination that is present in some cases of assimilation of the atlas have nothing to do with the production of neurological signs.

In basilar invagination the petrous tips

* Symptoms thought to be referable to cervical abnormality rather than to any associated disease.
† Signs thought to be referable to cervical abnormality rather than to any associated disease.

FIG. 6. Case 21. Lateral view. The left half of the posterior arch of the atlas is not assimilated but the right half is fused, making a small rim on the right half of the foramen magnum.

are elevated. In normal persons the petrous ridge in standard anteroposterior or posteroanterior projection slopes slightly downward as one follows it medially from the tegmen tympani or arcuate eminence. In only 4 cases of assimilation were the tips above the horizontal and then very little.

In normal skulls the clivus is usually concave posteriorly as shown by the midsagittal laminagram. The clivus is the posterior surface of the basi-occiput and basisphenoid and does not extend onto the dorsum sellae. In basilar invagination the clivus is usually convex posteriorly. In these cases of assimilation of the atlas the clivus was convex posteriorly in only 4 cases.

Asymmetry of the posterior edge of the foramen magnum is a frequent finding in patients with an Arnold-Chiari malformation. We had satisfactory films of the foramen magnum in 7 cases and 5 had asymmetrical posterior edges. Of these, 3 had either the Arnold-Chiari malformation or else herniation of the cerebellar tonsils. These do not include cases in which the asymmetry was due to fusion of one-half of the posterior arch to the occipital bone.

The most significant finding in cases of assimilation of the atlas with neurological signs was an odontoid process of abnormal size or in abnormal position or with abnormal mobility. In many cases all three factors were present. In the 2 cases (Cases 1 and 6) on which postmortem examination was carried out, there was a pit on the anterior surface of the lower end of the medulla oblongata into which the dens fitted. The height of the dens is the distance from its tip to the level of the superior facets of the axis on the lateral views. It is impossible to measure the height of the dens on anteroposterior views as it does not lie parallel to the film. The anteroposterior diameter is measured on the lateral film and is the greatest anteroposterior diameter at right angles to the long axis of the dens. The angle of the dens is the angle formed by the planes of the posterior surface of the body of the axis and the posterior surface of the dens below its conical tip. An angle of less than 180° implies that the dens bends backwards. In normal subjects the dens often bends backwards a little, this apparent bend probably representing a deep

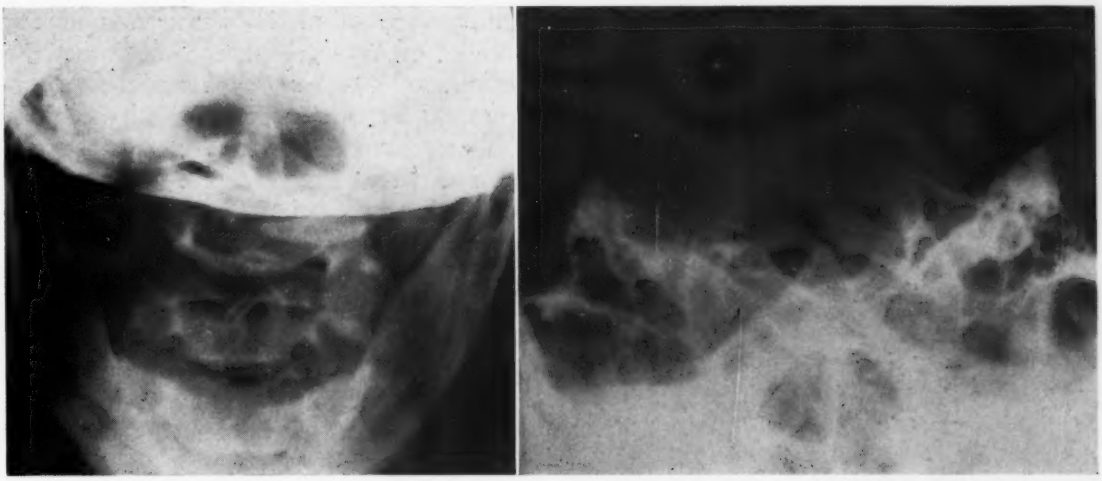


Fig. 7. Case 21. Anteroposterior occipital and open-mouth views showing the asymmetry of the right and left halves of the posterior arch of the atlas.

groove on its posterior surface in which the transverse ligament of the atlas lies.

Chamberlain's line is drawn from the posterior edge of the hard palate to the posterior lip of the foramen magnum, not to the fringe or to the assimilated posterior arch. The tip of the dens was well above Chamberlain's line in 8 of the 9 cases without neurological signs.

The foramen magnum line is drawn from anterior to posterior lip of the foramen magnum where it is formed by the occipital bone, not the assimilated anterior or posterior arches. In the 9 cases without signs, the tip of the dens was below this line in 4 and was 5, 7, 6, 6, and 3 mm. above it in the other 5 cases. It is fair to say that if the dens lies below the foramen magnum line the patient is probably asymptomatic. The only case (Case 23) with signs whose dens was below the foramen magnum line had a marked Arnold-Chiari deformity, the lower half of the fourth ventricle being in the neck along with both cerebellar tonsils and a fair amount of both cerebellar hemispheres as well. Many, if not all, of his symptoms

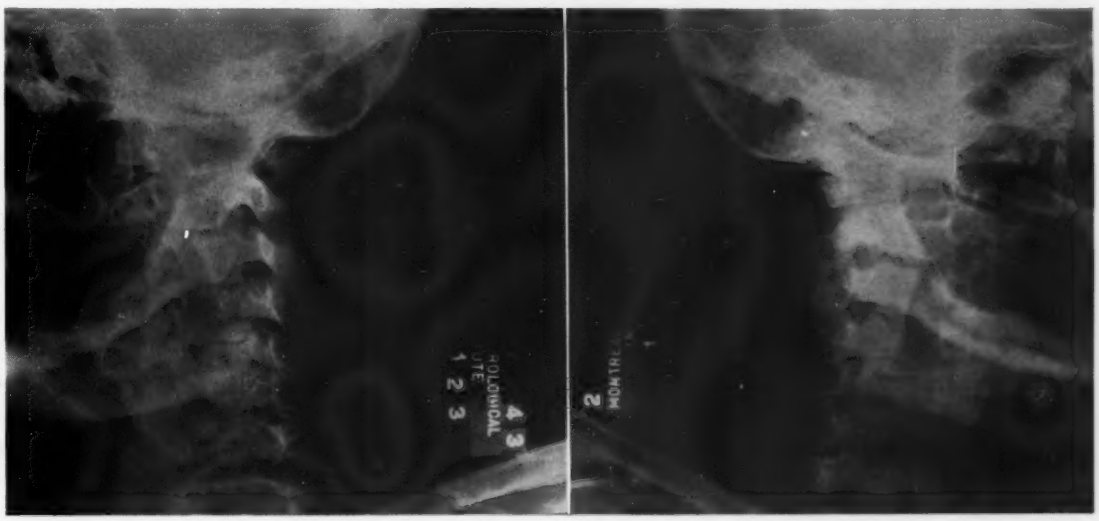


Fig. 8. Case 21. Right and left oblique views showing the transverse processes clear of the base of the skull. This position also shows the atlanto-axial joints.

Fig. 9. Case 5. Lateral view showing an anterior atlanto-occipital interval not filled with bone.

must have been due to the Arnold-Chiari deformity and few if any should be attributed to the bony abnormalities.

Of even more importance was the relation of the dens to the anterior arch of the atlas. If the dens was displaced backward (anterior dislocation of assimilated atlas of List) it encroached on the spinal canal (Fig. 17 and 18). The 9 cases without signs had 19 mm. or more space between the dens and the closest bony point behind it, either the posterior arch, the fringe or the foramen magnum. In the cases with signs the space averaged 20.5 mm., with 9 of the 16 cases being from 13 to 19 mm. It is possible to say that if the bony spinal canal at the level of the dens is 19 mm. or less in antero-posterior diameter the patient is probably having signs due to the bony abnormality. When the head is flexed this space may be 1 to 5 mm. smaller (Fig. 10, 13 and 14). In the 12 cases that had bending films there was abnormal mobility of the dens in 7. Of these 7 cases, 3 had no signs and 4 had.

The second and third cervical vertebrae were fused in 17 of the 25 cases. This fusion was surprisingly complete. There was a rudimentary disc space in less than half but in the others there was no trace of the C2-C3 disc. The apophyseal joints between C2 and C3 were completely obliterated but the pedicles of C2 were never fused with the pedicles of C3. The right and left intervertebral foramina were unusually distinct and smaller in caliber than usual. The laminae were always fused. The spinous processes might be fused or separate. Undoubtedly this signifies nonseparation of the fetal hemisclerotomes. The notochord did not undergo the usual increase in width at the disc space between the cartilaginous provertebrae C2 and C3. In 2 of these cases there were other fusions. In 1 case without fusion of C2 and C3 there was fusion of C4 and C5.

We attempted to count the total number of vertebrae and were successful in 7. In 6 others we were able to count the cervical and thoracic segments. At least 4 had abnormal numbers. Case 18 is most interesting. Counting the assimilated atlas, he had seven cervical segments without ribs. He had fourteen thoracic segments and fourteen pairs of ribs. The first ribs fused with with the second ribs and these articulated with the sternum just below the clavicle (Fig. 12). The fourteenth ribs were small and resembled lumbar ribs. In addition he had five quite normal lumbar vertebrae, five sacral and four coccygeal vertebrae. It might be possible to interpret this case as a manifestation of an occipital vertebra; with seven cervical vertebrae, the first having lost its hypochordal arch and being fused to the second, and the seventh bearing cervical ribs; plus thirteen thoracic vertebrae.

In 3 other cases there were eight cervical segments (counting the assimilated atlas), the eighth cervical bearing ribs on each side, but in none did these cervical ribs articulate with the sternum and in all the first thoracic ribs met the sternum immediately below the sternoclavicular joint.

In none of the cases with complete spine examinations did we find a lumbosacral anomaly.

In Case 14 we did not have films below the mid-thoracic level but this patient had a Klippel-Feil and dorsal mass deformity

with multiple hemivertebrae between C6 and T4 inclusive (Fig. 20).

Oil myelograms were attempted in 3 early cases but gave no information of value and resulted in much oil in the basal cisterns. We have discontinued this procedure. Gas myelograms were done in 11 cases and were much more informative. One can see the size, shape and position of the cord, the presence or absence of tonsillar herniation and occasionally the dural band. In 7 of the 11 cases operation was later carried out. The gas myelogram had shown tonsillar herniation in 2 cases and in each case it was confirmed. In 4 cases the oxygen myelogram showed no tonsillar herniation and this was confirmed. In 1 case (Case 23) the cisterna magna was visualized but the cervical subarachnoid space was not. This was thought to exclude both tonsillar herniation and Arnold-Chiari malformation but at operation a marked Arnold-Chiari deformity was found.

Operation was carried out in Cases 1, 2, 3, 6, 12, 14, 15, 16, 18, 20, 23, and 25. A true Arnold-Chiari malformation was found in Cases 1, 23 and 25. Tonsillar herniation alone was found in Cases 2, 6 and 14. A dural band was found in Cases 2, 6, 12 and 14.

The final diagnosis in the asymptomatic cases was as follows: Case 4, ependymoma of right lateral ventricle; Case 5, head injury; Case 9, sinusitis; Case 19, trigeminal neuralgia; Case 21, rupture of intervertebral disc C6–C7; Case 22, head injury; Case 24, focal epilepsy.

EMBRYOLOGY

In man the postotic mesenchyme undergoes partial segmentation, and at the end of the first month (12 mm. human embryo) three occipital myotomes can be fairly well seen. The axial

FIG. 10. Case 18. Lateral views in flexion and extension. In flexion the assimilated anterior arch is 3 mm. anterior to the anterior surface of the body of the fused second and third cervical vertebrae. In extension it lies 3 mm. behind the anterior surface of C2 and C3.

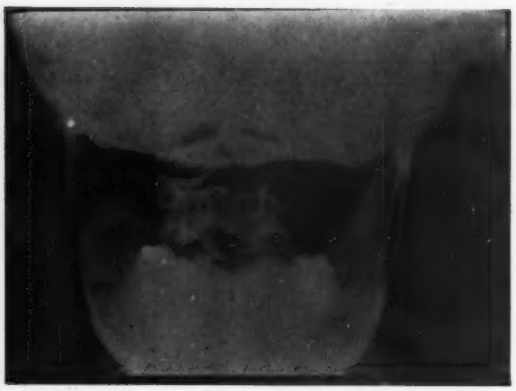


FIG. 11. Case 18. Open-mouth view showing asymmetry of atlanto-axial joints and fusion of C_2 and C_3.

mesenchyme does not form as clear-cut sclerotomes here as it does lower down. However, opposite the third occipital myotome the axial mesenchyme becomes divided into a clear anterior (cephalic) and a dense posterior (caudal) portion reminiscent of the spinal sclerotomes. The posterior dense portion has fairly well developed neural and chordal processes but no costal processes. The anterior clear part is in relation to the last hypoglossal nerve root. In the spinal region the dense posterior half of a sclerotome joins with the clear anterior half of the sclerotome subjacent to it to give rise to a mesenchymal provertebra. The occipital scleromere (posterior dense part) is not associated with the clear half of the first spinal sclerotome but remains continuous with the other tissue of its segment and with the rest of the basal plate. Therefore the occipito-atlanto joint is truly intersegmental and not to be compared to an intervertebral joint (disc) which is segmental. At a time when the basi-occipital and the bodies of the cervical vertebrae are cartilage the anterior half of the first cervical sclerotome is still composed of light mesenchymatous tissue.

In the 14 mm. human embryo the cartilage of the centrum of the atlas is connected with the cartilaginous arches by incompletely differ-

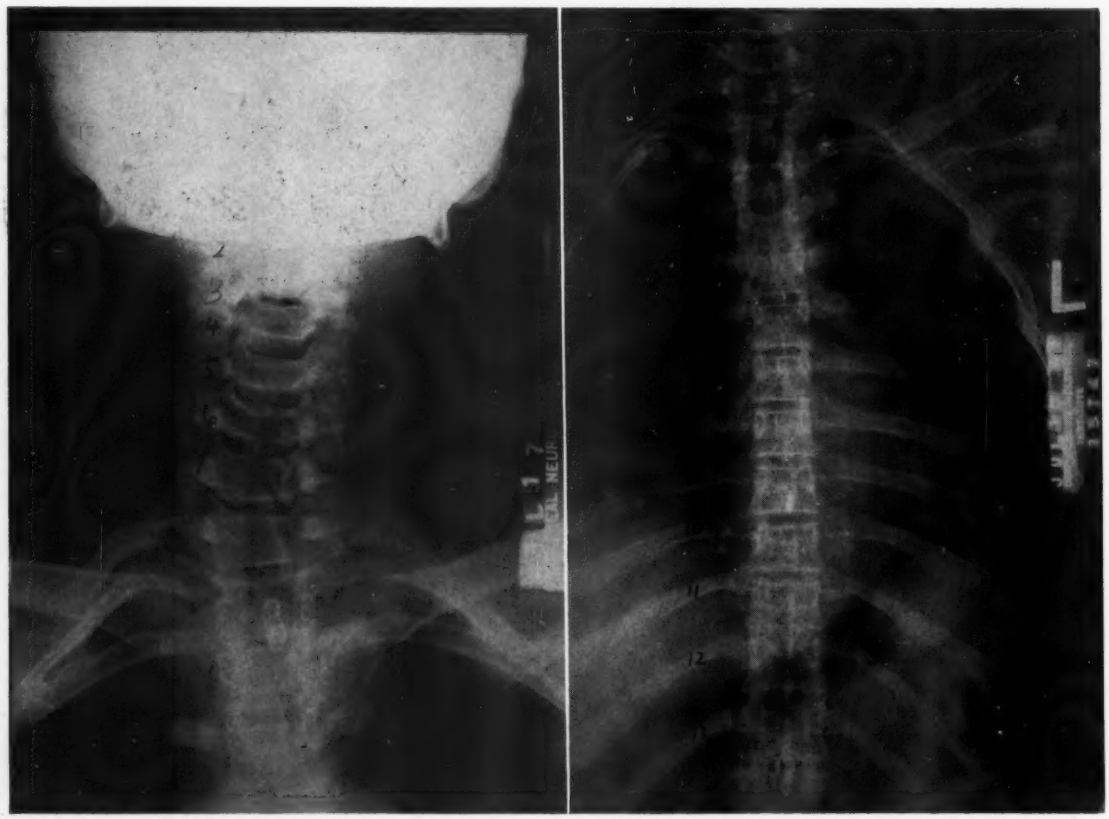


FIG. 12. Case 18. Anteroposterior views of cervical and thoracic spine showing seven cervical and fourteen thoracic vertebrae.

Fig. 13. Case 19. Lateral bending films showing flexion and extension taking place at the atlanto-axial joints.

entiated cartilage. Soon this poorly differentiated cartilage becomes transformed into dense blastemal tissue in which ligaments and joints will later develop. During chondrification of the more anterior cervical vertebrae there is a condensation of tissue on the ventral margin of each of the scleromeres. These condensed transverse bands connect the ventral ends of the blastemal neural processes and therefore may be called hypochordal arches. They are all transitory except the first one. In the first one the hypochordal arch chondrifies at the time of separation of the arches from the body (after the temporary fusion mentioned above). The cartilage of the hypochordal arch joins the cartilaginous neural arches on each side.

In the axis the dens represents the body of the first cervical vertebra. Union between the bodies of the first and second cervical vertebrae takes place through transformation of the intervertebral disc into hyaline cartilage. The first spinal somite may be termed proatlantal or suboccipital, as the nerve of this segment supplies the suboccipital muscles. The anterior half of this sclerotome does not unite with the occipital scleromere in man but becomes the tip of the odontoid process. It unites with the occipital in reptiles and is called the proatlas. The rest of the odontoid is formed from the first spinal sclerotome and the anterior half of the second (atlantal) sclerotome (Fig. 26).

The spinal nerves are situated in relation to the anterior clear halves of the sclerotomes. Since the posterior dense half of a sclerotome joins the anterior clear half of the subjacent sclerotome, the spinal nerve comes to lie below its vertebra. Since the atlas forms from the anterior clear halves of the first and second spinal sclerotomes and the posterior dense half of the first spinal sclerotome there are two spinal nerves, C1 and C2, associated with it, one nerve above and one nerve below (Fig. 27).

It was stated above that the third occipital sclerotome had a scleromere and that this scleromere has fairly well developed neural and chordal processes. If this segment does not become incorporated into the cranium completely it may be termed manifestation of an occipital vertebra or vertebralization of the occiput. The segment involved is that below the hypoglossal foramen. It is rare to see a complete, or nearly complete, segment such as this but it is not so rare to see some accentuation of the edges of the foramen magnum, for example, a third occipital condyle, a paramastoid process or a posterior bony lip. It is essential that there

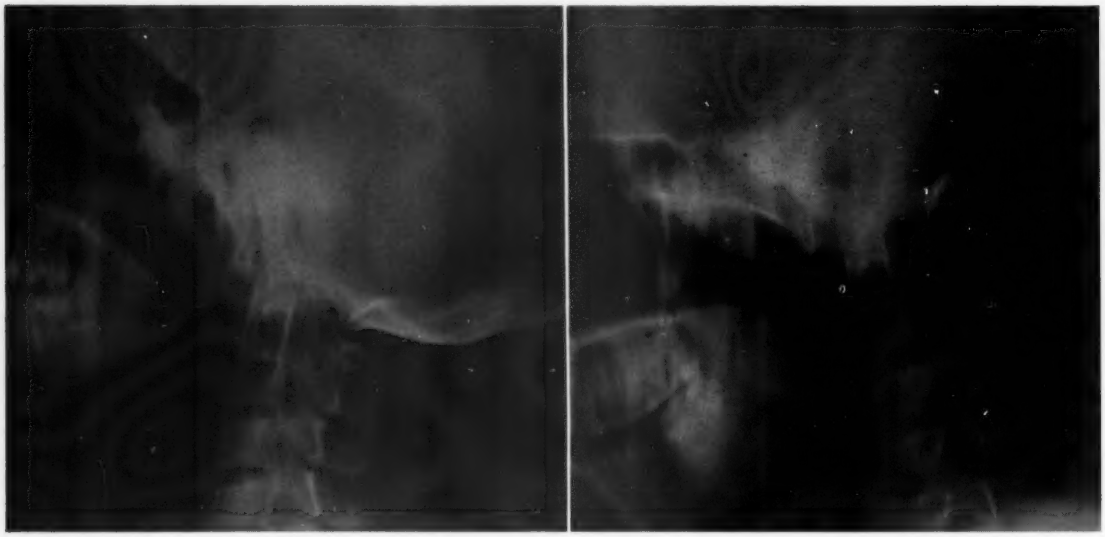


FIG. 14. Case 15. Lateral laminagrams in flexion and extension showing rocking of the atlas on the axis and abnormal mobility of the dens.

be no foramen for the vertebral artery or suboccipital nerve between this segment and the occiput. In the case of occipitalization of the atlas (assimilation of the atlas into the occipital bone) one must assume that the hypochordal arch of the atlas with its attached neural arches is continuous with the basal plate (occipital sclerotomes). The centrum of the atlas fuses with the centrum of the axis, and the centrum of the atlas separates itself from the hypochordal arch by the transformation of incompletely differentiated cartilage into blastemal tissue, as mentioned above. The fact that approximately 50 per cent of cases of assimilation of the atlas have an associated fusion of the second and third cervical vertebrae (both bodies and arches) may signify the absence of ingrowth of the myocoele (v. Ebner) into the third or axial somite and might be evidence in favor of diffusion of a chemical organizer, or else the lack of organizer in the whole area. A comparative study of the suboccipital and long cervical muscles in normal subjects and in these persons might show variations in their origins.

Some writers have used a nomenclature in

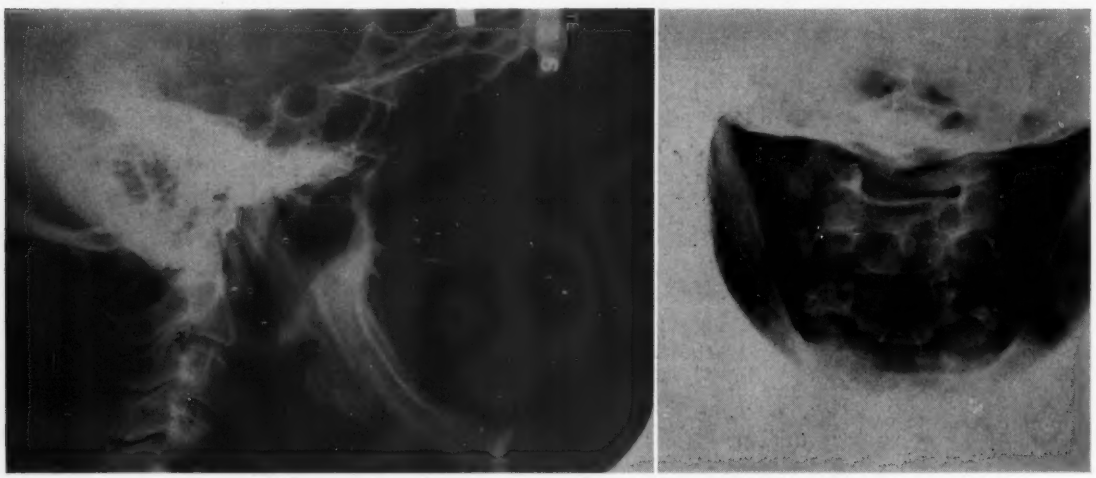


FIG. 15. Case 7. Lateral and open-mouth views showing fusion of only the right half of the posterior arch.

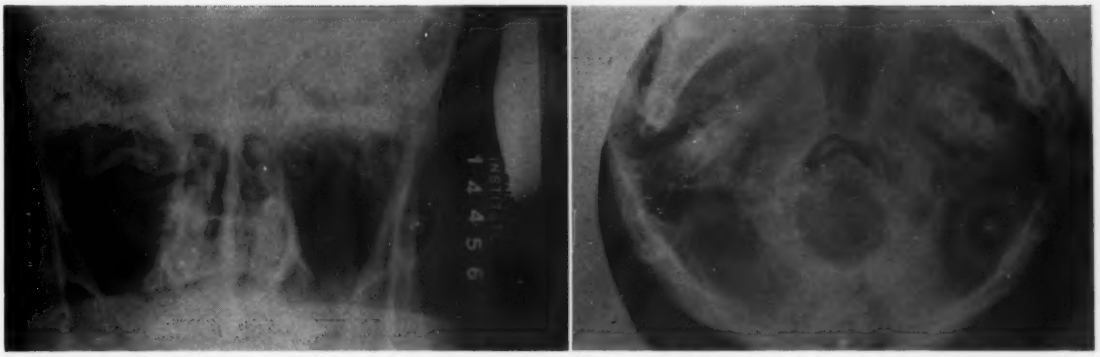


Fig. 16. Case 7. Anteroposterior and submentovertical views of the skull showing a separate paramastoid process on the left side and a fairly normal transverse process on the right. There is an atlanto-occipital joint on the right.

which four occipital somites are named, the last one being called a proatlantal somite (Foriep, Fraser). The topmost portion of the atlas is variously stated to be from the last hypoglossal somite or from the first vertebral somite.

In the anatomical literature several criteria have been advanced to allow differentiation of occipitalization of the atlas from manifestation of an occipital vertebra when only the dried skull is available for examination. At various times the various criteria have been proved not valid in all cases. Even if the complete spine is available it may not help. Probably criteria based on the position of the hypoglossal and suboccipital nerves and vertebral artery are most reliable but even these have been questioned (Gladstone and Erichson-Powell, Fraser).

In calling on phylogeny to clarify the developmental details of this region, one must realize that the craniovertebral junctions in different species may be at different segmental levels. The nerve of the tongue in one species may not be homologous to the nerve of the tongue of another (Gladstone and Wakeley).

The primitive vertebral column possessed in each of its segments four pairs of main elements. The principal elements (basalia) consisted of basiventralia on the ventral side of the

Fig 17. Case 20. Lateral view showing the odontoid process lying in the middle of the foramen magnum.

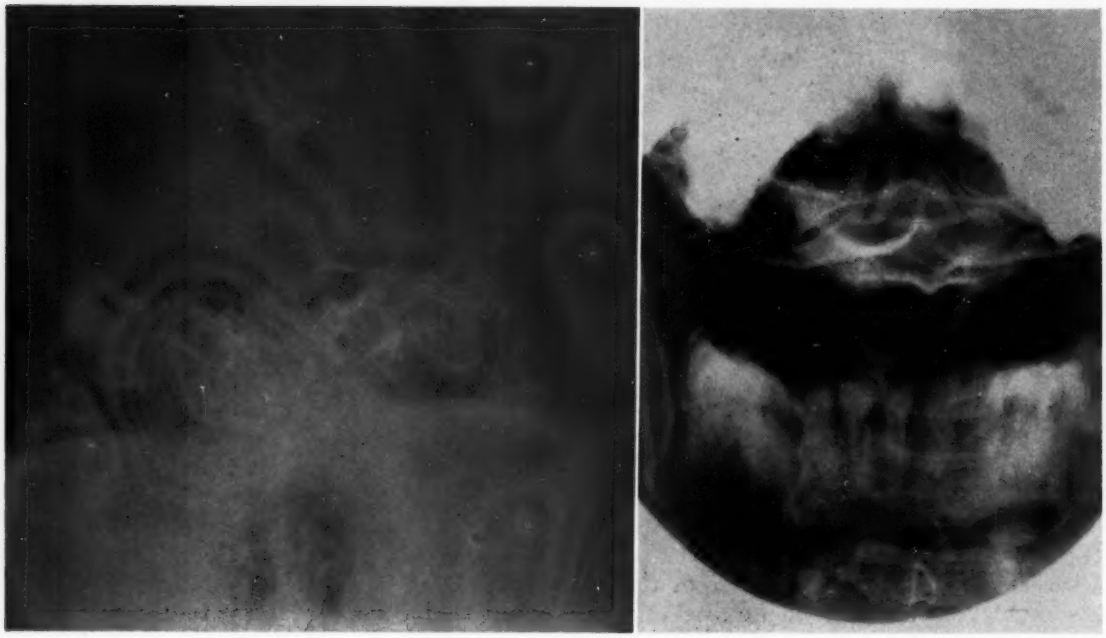


FIG. 18. Case 20. Open-mouth and anteroposterior occipital views showing the odontoid process to better advantage. Note the asymmetry of the atlanto-axial joints. The height of the dens above the assimilated posterior arch is best appreciated in the anteroposterior occipital view.

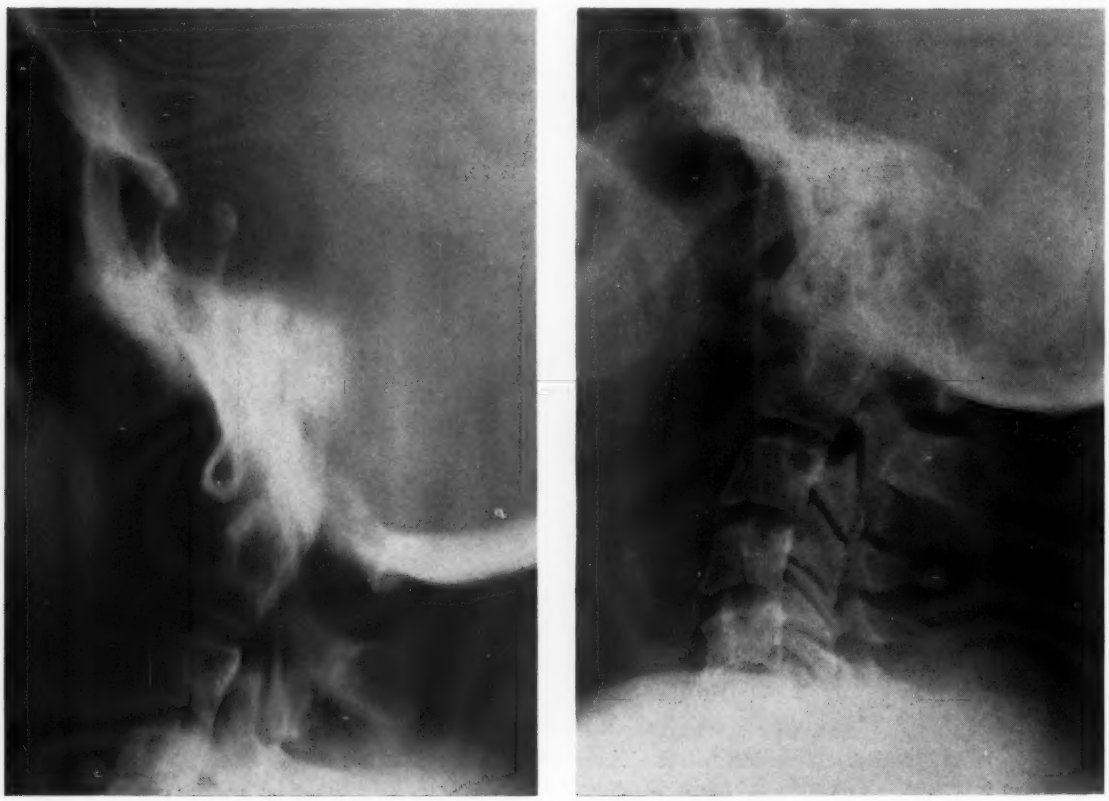


FIG. 19. Case 14. Lateral laminagram and lateral film.

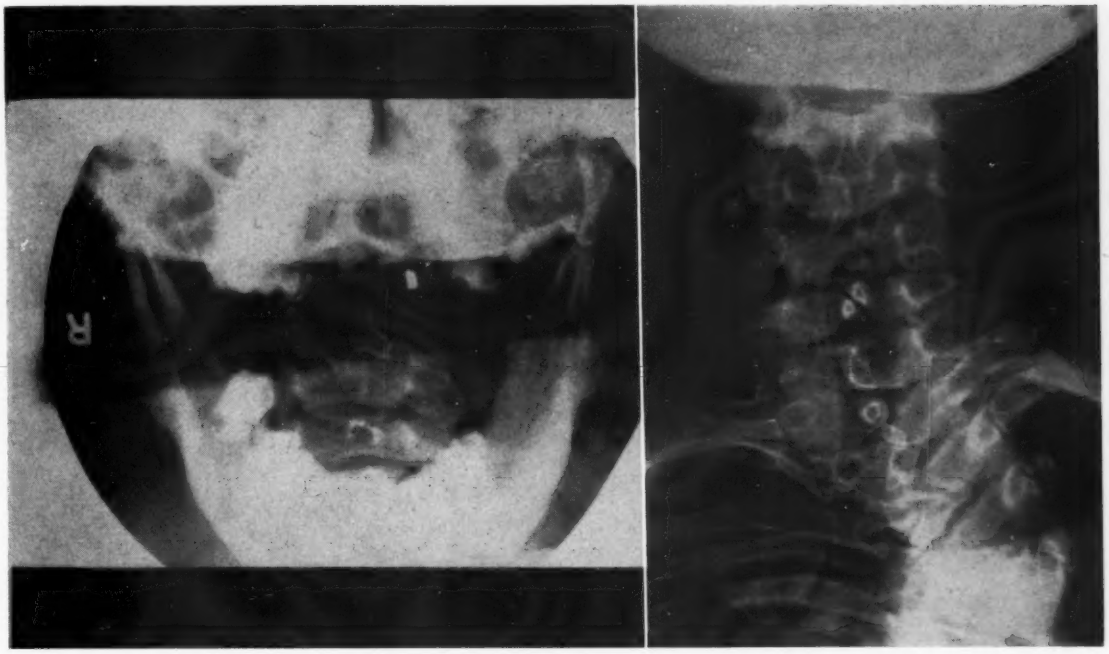


Fig. 20. Case 14. Open-mouth and anteroposterior views.

neural cord and basidorsalia supported on the basiventralia and covering the spinal cord. There were secondary elements behind them (interbasalia) consisting of interventralia and interdorsalia. These main elements might be all present or might be modified in various ways. The mammals appear to have used an interbasal structure, probably interdorsal, to make the centrum and this secondarily acquired fusion with the basidorsal. The basiventral element thus is not represented in a mammal save possibly by the anterior ventral rim of the centrum or a part of the intervertebral disc. This so-called hypochordal arch is represented in the atlas, however, as the anterior arch. These findings, in addition to Barge's demonstration that the atlanto-occipital joint is intersegmental and not segmental, should lead to great caution in assessing the occipito-atlanto-axial region in terms of vertebrae.

CLINICAL ASPECTS

There has been some question in our minds as to whether assimilation of the atlas in itself is ever productive of symptoms or signs without encroachment upon the bulb or cord by associated soft tissue deformities or bony malformations. The most frequent of the latter was a posteriorly displaced odontoid process of the axis which occurred in 15 of the 25 cases (60 per cent of the time) and in 12 of the 18 cases who had symptoms thought to be attributable to cervical abnormality. Our definition of posterior displacement is a dens lying 4 mm. or more posterior to the anterior arch of the atlas. It was posteriorly displaced in 2 patients who had no symptoms or signs referable to cervical or medullary involvement, but in these there was ample room for the cord to pass through the canal. The posterior displacement was 4 mm. as opposed to the marked displacement usually seen in the symptomatic cases—the odontoid sometimes being as much as 12 mm. from the anterior arch. The important consideration is, of course, the amount of space available to the cord as measured from the posterior surface of the dens to the posterior border of the foramen magnum, or other *closest* posterior bony point. This has been discussed previously with the roentgenographic analysis.

Another frequent finding was a thickened band of dura posteriorly (usually at the

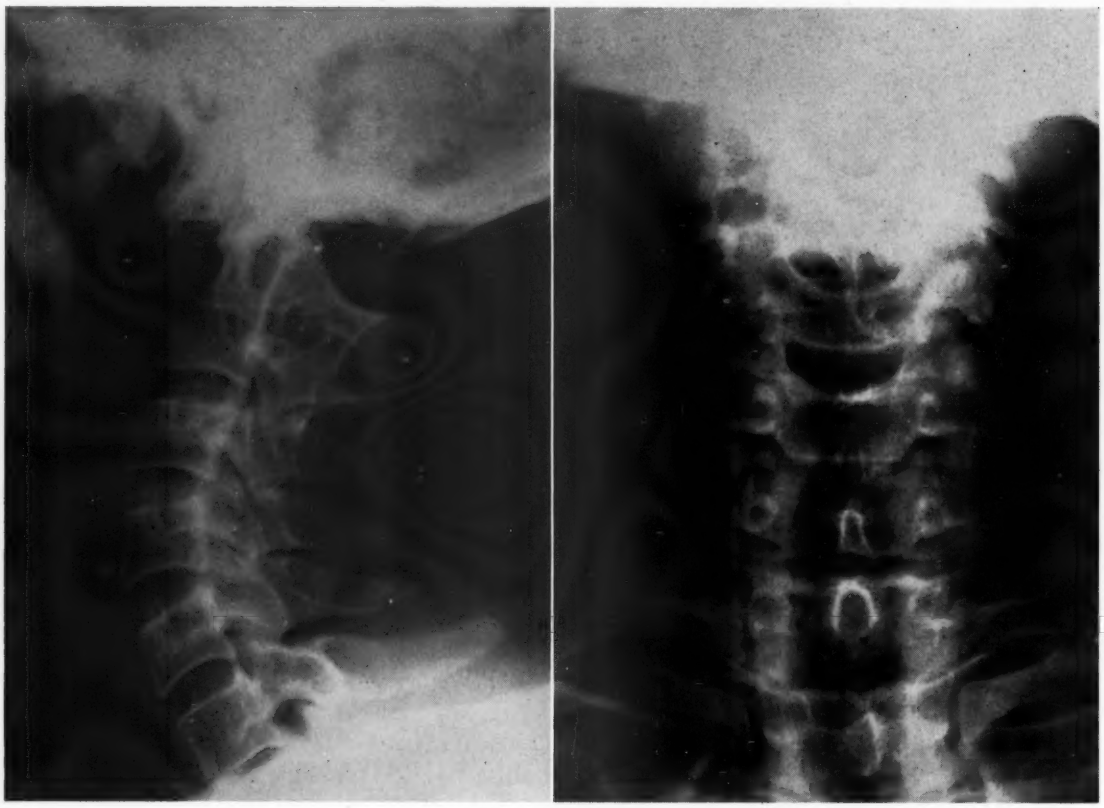


FIG. 21. Case 1. Anteroposterior and lateral views.

junction of the occipital bone and the spine) which constricted the cord, in one instance to a degree sufficient to obliterate its normal pulsations, these returning only after dissection away of the band. Thickened dural bands were noted in 4 of the 12 cases which were surgically explored. Also notable was the association of cerebellar tonsil herniations with the cases of assimilation of the atlas, this finding being present in 3 of the 12 cases where it was either seen surgically or by air encephalography.

Fusion of C2–C3 vertebrae occurred in over half the cases (17 out of the 25), but we do not feel that in any instance was the fusion of these vertebrae responsible for any encroachment on the spinal canal, and hence are inclined to disregard this finding as significant in the production of either signs or symptoms.

Cervical intervertebral disc protrusion was shown by opaque myelography in 5 cases. In Case 21 we considered the symptoms and signs to be due to the disc protrusion. In Cases 3, 10, 15 and 18 the disc protrusions were small and we considered that they were not productive of neurological signs.

Platybasia was rare, occurring in 4 cases. Cerebrospinal fluid block (either partial or complete) by manometric examination occurred in 6 cases, and in at least 2 was responsible for intracranial pressure symptoms such as headache and papilledema.

Of the 25 cases analyzed, 20 were male and 5 were female. The age of onset of symptoms varied from eight to fifty-one years, the symptoms notably being of short duration prior to the seeking of medical advice by the patient. Eighteen had symptoms and 16 had signs which were thought to be referable to their cervical abnormality. Of the 7 asymptomatic cases discovered during routine roentgen examination for other complaints, 5 had some associated cervical abnormality such as a displaced

odontoid process, fused vertebrae, upper cervical disc protrusion, etc. The reason for lack of symptoms was thought to be lack of encroachment on the neuraxis as already discussed.

The presence of associated congenital abnormalities was noted in 5 cases (20 per cent). These included hypoplasia of the jaw, incomplete cleft of the nasal cartilage, hypospadias, cleft palate, congenital deformity of the external ear, cervical ribs, and incomplete rotation of the kidney with anomalous renal vessels. Associated general diseases were present in 15 of the cases, but it was not felt that any correlation could be made as compared to the incidence of these conditions in the general population.

The Symptomatic Cases. All symptoms have been tabulated in Table II, but where symptoms were thought to be explicable on the basis of other disease (such as brain tumor in Case 4 or disc protrusion in Case 21), that case has been excluded from the "symptomatic group." Only the cases whose symptoms could be explained by the lesion at the foramen magnum and upper cervical region have been called symptomatic. There were 18 cases with symptoms by this criterion.

The appearance of symptoms after head or neck trauma in a previously asymptomatic person, and in whom there was no evidence of a separate lesion from the trauma itself, was quite striking in 6 cases, all of whom definitely related their complaints to the injury.

The question of previous misdiagnosis was an interesting one, but rather a difficult one to evaluate. It was finally decided to use as a criterion the actual diagnosis, and sometimes treatment, of the patient for symptoms or signs which were later (upon its discovery) thought to be a result of the cervical abnormality. Proof of the validity of this thought was based in some cases upon the direct correction of the situation by operation and in others by reasoning where clear anatomical compression of the neuraxis was evident by roentgenological examination plus clinical signs. With this criterion, 38.9 per cent (7 of the 18 symptomatic cases) had been previously misdiagnosed—by far the most frequent diagnosis having been multiple sclerosis.

Regarding the symptoms themselves (18 cases), weakness or ataxia of the lower extremities was the most frequent complaint occurring in 13 patients. Weakness or ataxia in the upper extremities was less common, only 9 having this complaint. Eight complained of weakness or ataxia in both upper and lower extremities.

Numbness and/or pain in the extremities was the next most common symptom, 10 complaining of this in the upper extremities and 3 in the lower extremities (all 3 of which also had numbness or pain in the upper extremities).

Headache occurred in 9 cases. This was

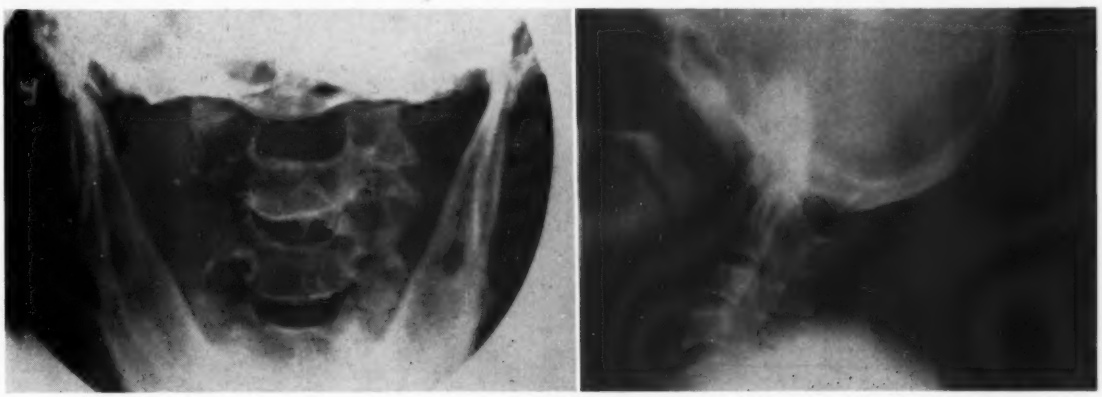


Fig. 22. Case 1. Open-mouth view and lateral laminagram. There is asymmetry of the atlanto-axial joints and of the transverse processes of the atlas. The anterior atlanto-occipital interval is closed by bone. The dens is lying well above the foramen magnum line.

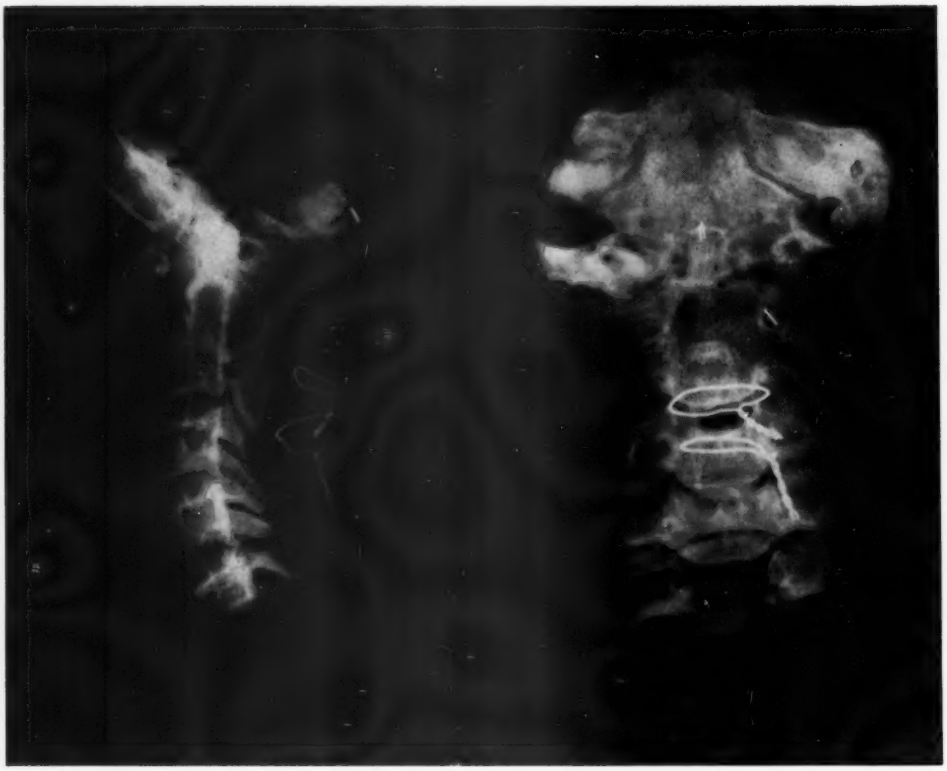


Fig. 23. Case 1. Anteroposterior and lateral views of the autopsy specimen. The laminae and spines have been removed. The fused deformed transverse processes are still attached to the atlas and the left petrous process.

Fig. 24. Case 24. Anteroposterior and lateral views. On the right side there is an atlanto-occipital joint. The right transverse process and the right half of the posterior arch are not attached to the occipital. There is a suggestion of a left atlanto-occipital joint space at a slightly higher level. The left transverse process is attached to the occiput but the left half of the posterior arch is not.

almost always confined to the posterior two-thirds of the cranium, but strangely was never shooting in character like an occipital neuralgia, but rather dull and aching, sometimes constant and sometimes brought on by coughing or neck movements. Neck pain itself was present in 7 of the 18 cases who had symptoms.

Seven of the cases had visual disturbances, *i.e.*, blurring of vision or diplopia. One of these was explained on the basis of papilledema thought to be due to cerebrospinal block at the foramen magnum. The mechanism in the other cases is not clear, there being no associated disease which would explain visual difficulties. Another interesting, but unexplained, complaint was the relative frequency of buzzing in the ears or earache, this having been mentioned prominently by 5 of the patients.

Dizziness was a complaint in 3 of the cases. In no instance did we have the impression of a true vertigo, and we have interpreted it as probably a subjective sensation concomitant with the ataxia which all 3 manifested.

Bulbar involvement led to complaints of difficulty in swallowing, regurgitation of fluids through the nose, poor phonation, etc., in 4 of the cases. One patient complained of decreased sweating on the left side of his face. This was the only instance of a subjective complaint referable to the sympathetic system, although 3 cases showed signs of sympathetic involvement, as will be discussed later.

Fig. 25. Case 4. Lateral view. One-half of the posterior arch forms a rim on the foramen magnum. The other half is rudimentary but bears a ponticulus converting the arterial groove into a foramen.

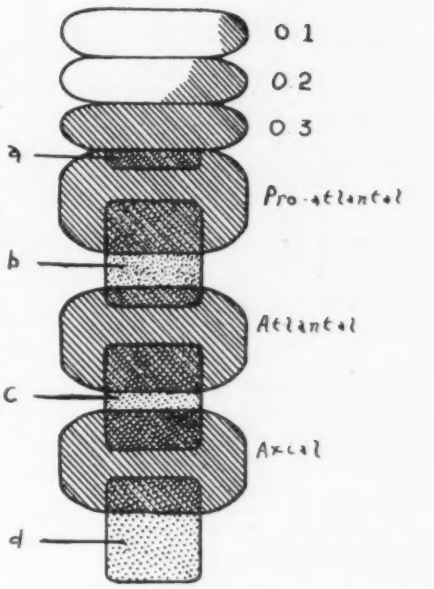


Fig. 26. Diagram of the three occipital and upper three cervical sclerotomes after Gadow (from Keith). The shaded parts of the occipital segments represent the persistent parts: (a) the centrum of the pro-atlas, (b) of the atlas, (c) of the axis, (d) of the third cervical vertebra.

Bladder complaints were rare, only 2 patients complaining of urinary difficulties which could have arisen from a neurological lesion.

Cases Showing Neurological Signs. There were 16 cases who showed signs which we felt were attributable to the foramen magnum and upper cervical abnormalities under discussion. Although all signs noted in each patient are tabulated in Table II for the sake of completeness and accuracy, those whose signs could have been explained by other disease processes are not included in this group of 16.

The objective neurological examination,

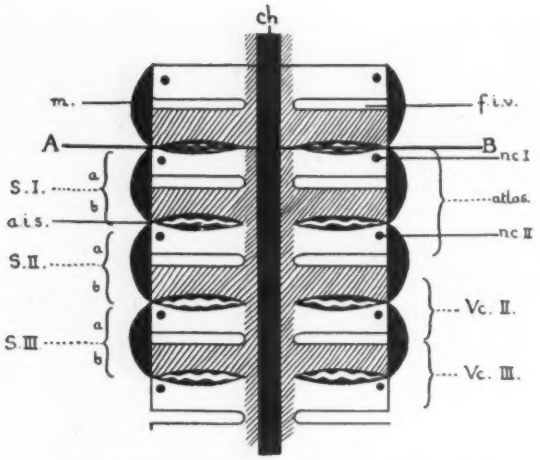


FIG. 27. Diagram indicating the position of the cranio-vertebral boundary (after Barge).

ch.	Chorda dorsalis.
M.	Myotome.
A.B.	Cranio-vertebral boundary.
S.I., S.II., S.III.	First, second and third spinal sclerotomes.
a.	Cranial semi-segment.
b.	Caudal semi-segment.
nc. I.	First cervical nerve.
nc. II.	Second cervical nerve.
Vc. II.	Second cervical vertebra.
Vc. III.	Third cervical vertebra.
f.i.v.	Fissura intervertebralis (v. Ebner)
a.i.s.	Arteria interprotovertebralis.

in the 16 cases who had signs, most frequently revealed long tract signs (hyperreflexia, Babinski, Hoffmann, weakness, etc.), some or all of these being present in the upper extremities in 13 and the lower extremities in 11 cases. Long tract signs never occurred in the lower extremities without similar signs in the upper extremities in the same patient. Spasticity occurred in 5 cases.

Frank ataxia was noted in 6 cases in the upper extremities and in 5 in the lower extremities. These were not the same cases, some showing ataxic gait without upper extremity involvement, and others showing ataxia of arm and hand movements without involvement of the lower extremities. Nystagmus was a prominent finding; it occurred in 8 patients. Evidence of a bulbar lesion (cranial nerve palsies, etc.) was present in 5 cases.

Posterior column signs (touch, vibration, position sense) were somewhat less common, suggesting that the main damage to the cord was occurring anteriorly, presumably by the displaced odontoid process of the axis, rather than posteriorly by the dural band. Not all the cases showing posterior column signs had a dural band or cerebellar tonsil herniation posteriorly. Posterior column deficit was found in the lower extremities in 7 cases and in the upper in 3 cases. Upper extremity involvement was never present without concomitant involvement of the lower extremity in the same patient, the reverse of the situation noted regarding the long tract signs. Five cases showed impairment of two-point discrimination or stereognosis in the hands and 2 in the feet.

Six cases showed objective hypesthesia in the upper extremity and 4 in the lower. There was 1 case of hemi-anesthesia suggesting involvement of the lateral spinothalamic tract in the cervical region.

Neck pain on examination was notably rare, only 1 case demonstrating this. One case only showed head tilt.

Sympathetic involvement was seen in 3 cases, 2 of these showing Horner's syndromes. Objective bladder testing was not carried out in any of this series.

CONCLUSIONS

The major symptoms, then, of cervical cord compression due to the soft tissue and bony abnormalities associated with occipitalization of the atlas fall into a group comprising most notably weakness and ataxia of the lower extremities. Numbness and pain in the upper extremities is a prominent complaint, although the upper extremities are often involved on the motor side also. Sensory complaints in the lower extremities seem to be rare. Occipital headache may be present, as may blurring of vision and diplopia. Bladder symptoms are notably rare. Head or neck trauma would seem to play some part in the onset of symptoms in a condition which has presumably been present since birth.

The objective findings comprise chiefly hyperreflexia, Babinski and Hoffmann reflexes, weakness, and other long tract signs

in both the upper and lower extremities. Ataxia may be present to a marked degree, and nystagmus is frequent. Sensory findings are less frequent, but posterior column signs may be seen in the lower extremities —rarely in the upper. Hypesthesia is also seen in the extremities.

A glance at the above syndrome immediately recalls the similarity to multiple sclerosis, especially with the evidence of fluctuation in the intensity of the signs and symptoms in some cases. The fact that over one-third of these cases were previously misdiagnosed, and most frequently as multiple sclerosis, would lend emphasis to the possible confusion of the entities. In our opinion, therefore, the knowledge of and search for such cervical anomalies in cases presenting the syndrome described is of the utmost importance, especially in view of the possibility of benefit by surgical correction of the condition.

D. L. McRae, M.D.
McGill University
3801 University St.
Montreal, P. Q., Canada

REFERENCES

1. Chamberlain, W. E. Basilar impression (platybasia). *Yale J. Biol. & Med.*, 1939, *11*, 487–496.
2. Ebenius, B. Roentgen appearance in 4 cases of basilar impression. *Acta radiol.*, 1934, *15*, 652–656.
3. Fraser, J. E. The Anatomy of the Human Skeleton. Fourth edition. J. & A. Churchill, Ltd., London, 1946.
4. Gladstone, R. J., and Erichson-Powell, W. Manifestations of occipital vertebrae and fusion of atlas with occipital bone. *J. Anat. & Physiol.*, 1914–1915, *49*, 190–209.
5. Gladstone, R. J., and Wakeley, C. P. G. Variations of occipito-atlantal joint in relation to metameric structure of cranio-vertebral region. *J. Anat.*, 1924–1925, *59*, 195–216.
6. Harrower, G. Variations in region of foramen magnum. *J. Anat.*, 1922–1923, *57*, 178–192.
7. Keith, A. Human Embryology and Morphology. Sixth edition. Edward Arnold & Co., London, 1948.
8. List, C. F. Neurologic syndromes accompanying developmental anomalies of occipital bone, atlas and axis. *Arch. Neurol. & Psychiat.*, 1941, *45*, 577–616.
9. Peyton, W. T., and Peterson, H. O. Congenital deformities in region of foramen magnum; basilar impression. *Radiology*, 1942, *38*, 131–144.
10. Schüller, A. Zur Röntgen-Diagnose der baselen Impression des Schädels. *Wien. med. Wchnschr.*, 1911, *61*, 2593–2599.

DISCUSSION*

Dr. Carl List, Grand Rapids, Mich. For a long time the developmental anomalies of the craniovertebral border have remained in a twilight zone between neurology and roentgenology. Dr. McRae and Dr. Barnum's paper has clarified many of the controversial points, but there is still a good deal of confusion in the terminology since many authors use promiscuously terms for skeletal deformities and those of neurologic syndromes.

The neurologic syndromes may be produced by several mechanisms. First, they may be due to direct local compression by the bony deformity. Secondly, they may be due to independent, but associated developmental anomalies of the central nervous system. Thirdly, there may be combinations of the two mentioned groups. Finally, the secondary effects of increased intracranial pressure or impaired cerebrospinal fluid circulation may, per se, produce neurologic signs.

Fundamentally, the deformities may be classified in two groups. First, there may be anomalous segmentation, *i.e.*, a disturbance in the transverse plane of the body. Assimilation of the atlas or the manifestations of an occipital vertebra are good examples for this type of disturbance. I would like to show you here (slide) what happens when the atlas is assimilated. The head and the assimilated atlas may pivot forward on the axis. Films taken in various positions of the neck demonstrate the dens in apposition to the anterior arch of the atlas in the extended and neutral positions; in the flexed position, however, the odontoid process may impinge on the medulla. This is an example of a mobile congenital dislocation; in other cases, the dislocation is fixed.

A second group of malformations occurs in the longitudinal plane of the body, and manifests itself in a failure of fusion in the midline. This group is also known under the term "dysraphic disorders." Dysraphism may include both bony structures as well as the central nervous system. As an illustration I would like to show you slides of two familial cases of cleidocranial dysostosis (mother and daughter) with numerous dysraphic anomalies. (Slide)

* See also further discussion on page 89.

The mother has no clavicles, and exhibits a spina bifida in the upper dorsal region. (Slide) Her skull roentgenogram reveals a defect in the midline of the skull. Furthermore, eburnation of the temporal bones is noteworthy. (Slide) A mild degree of basilar impression is present.

(Slide) Roentgenograms of the daughter show rudimentary clavicles, cervicodorsal spina bifida, and in the skull, again, a large midline cleft. In addition, there is a striking degree of basilar impression (slide).

The considerable elevation of the basiocciput is also clearly demonstrated by laminograms taken in the sagittal and transverse planes (slides).

In closing, I would like to show a few illustrations of the so-called Arnold-Chiari deformity. This is a developmental anomaly of the hindbrain which is commonly associated with the aforementioned bony changes. At operation, one sees at first the shelf-like structure of the assimilated atlas (slide). After removal of the bone (slide) the underlying Arnold-Chiari malformation is indicated by a peculiar lobulated prominence of the midline dura. There is a characteristic circular ligamentous band constricting the dura at the foramen magnum. After opening the dura (slide) one sees the elongated cerebellar tonsils hanging down into the spinal canal (Arnold deformity) and a posterior kinking of the medulla (Chiari deformity). Some authors have attempted to explain the Arnold-Chiari deformity entirely by mechanical traction, but others, including myself, are more inclined to consider it a local developmental malformation.

Vol. 70, No. 1

AGENESIS OF THE CORPUS CALLOSUM WITH CONCOMITANT MALFORMATIONS, INCLUDING ATRESIA OF THE FORAMENS OF LUSCHKA AND MAGENDIE*

By EUGENE F. VAN EPPS, M.D.

IOWA CITY, IOWA

AGENESIS of the corpus callosum has been described intermittently in the literature since 1812 when Reil[18] first described the lesion in an autopsy specimen. It was not until 1934, however, that Davidoff and Dyke[6] and Hyndman and Penfield[12] published their findings simultaneously on the recognition of this condition by means of encephalography or ventriculography in the living subject.

The characteristic roentgenographic appearance of the air-filled ventricular system seen in agenesis of the corpus callosum has been published by Davidoff and Dyke[6] and is presented in Table 1. Hyndman and Penfield[12] were the first to make a distinction between complete and partial absence of the corpus callosum. This was based upon good filling of the third ventricle and upon alterations in the contour and position of the elevated third ventricle. One of their cases showed absence of the splenium only and was well demonstrated in their published report. Subsequently, Pospiech[17] in 1942 re-emphasized the findings in complete and partial agenesis of the corpus callosum.

TABLE I

CHARACTERISTICS SEEN ON ENCEPHALOGRAPHY IN AGENESIS OF THE CORPUS CALLOSUM

1. Abnormally great separation of the lateral ventricles
2. Concave mesial margins and pointed dorsal margins of lateral ventricles
3. Enlargement of the atria and temporal horns
4. Elongation of interventricular foramens
5. Dorsal extension and dilatation of third ventricle
6. Radial arrangement of mesial cerebral sulci

(From Davidoff and Dyke.[6])

Several associated anomalies of the central nervous system seen in cases of agenesis of the corpus callosum have been reported from postmortem protocols and are important to the roentgenologist, since many of them are demonstrated by encephalography or ventriculography, and have been reported in the literature.[1,3–15,20–23,25] These consist of the following: cortical atrophy, comparative atrophy of one hemisphere, hydrocephalus, porencephaly, including porencephaly of the cerebellum,[23] cysts of the septum pellucidum when it is present, absence of the septum pellucidum (in all cases of complete agenesis), microcephaly, and dilatation of the cisterna magna.[11]

It is not the purpose of this paper to discuss at any length either the clinical manifestations of this condition, or the etiologic factors thought to be responsible for producing the agenesia, but it is thought wise to present a short summary of the embryology of the corpus callosum.

It has been generally agreed that the corpus callosum in the human fetus develops between the third and the fifth month. Marburg,[15] however, has stated that cases of genuine agenesis of the corpus callosum are produced by lesions of varied etiology within the first fourteen days of fetal life. I would like to quote from his description of the development of the corpus callosum.

Anterior to the lamina terminalis a slight thickening of the wall of the hemisphere appears in the midline—Hochstetter's commissural plate. The raphe of the corpus callosum indi-

* From the Department of Radiology, College of Medicine, State University of Iowa, Iowa City, Iowa. Presented at the Fifty-second Annual Meeting, American Roentgen Ray Society, Washington, D. C., Sept. 25–28, 1951.

cates a fusion of two plates in the midline, obviously occurring before the closure of the anterior neuropore. Evidence of this, however, is lacking. This plate is only a conduction tissue, called Leitgewebe by Held, to facilitate the crossing of the fibers. These fibers are condensed dorsally as the corpus callosum and ventrally as the anterior commissure, whereas the remnant of the commissural plate between is represented by the septum pellucidum. . . . Thus the corpus callosum, the anterior commissure and the psalterium, as well as the septum pellucidum, are integral parts of the commissural plate, a lesion of which, in the midline, will affect all of these structures. During the presence of the commissural plate—the first fourteen days of fetal life—the vascularization has not progressed far enough to enable one to speak of an anterior cerebral artery.

According to Marburg, a developmental disturbance of the commissural plate produces a complete agenesis of the corpus callosum and is characterized by the absence, or in cases of less intensity and extent, by partial absence or reduction of the structures in the midline: the corpus callosum, the anterior commissure, the psalterium and the septum pellucidum. In all the cases the callosal fibers are heterotopic and appear as a longitudinal bundle. The gyrus cinguli in its middle position is either absent or atrophic, resulting in the radial arrangement of the sulci of the medial wall of the hemisphere, as well as the absence of the common section of the parieto-occipital and calcarine fissure. Eventually hydrocephalus develops.

Bruce's[2] subdivisions of the stage in the embryonic development at which arrested development occurs has been used by many authors and is helpful in determining the approximate time a lesion would have to appear in order to produce a set of abnormalities.

First three weeks: Complete absence of the corpus callosum. Hemispheres and ventricular system are a single, undivided unit.

Four weeks through three months: Absence of corpus callosum and anterior commissure, but longitudinal of cerebral hemispheres.

During fourth month: Absent corpus callosum with anterior commissure present.

End of fourth month: Genu of corpus callosum and anterior commissure present.

Sufficient deviations from the above schedule have occurred so that there should be no rigidity in applying it to specific cases.

ETIOLOGIC FACTORS

In the genuine agenesis of Marburg it is important to know that whatever lesion produced the abnormality it had to appear within fourteen days of conception, since, as mentioned above, the commissural plate forms during this period of fetal life. When the agenesis is due to arrested development, vascular lesions, porencephaly, hydrocephalus, or inflammation, the defect is secondary, even when it occurs in fetal life. It is apparent that only the period of developmental arrest is important; *i.e.*, the time of development of the malformation. Heredity does not play an important part, at least in humans. Infections such as rubella in the mother have been reported by Friedman and Cohen.[10] Congenital syphilis has been implicated at one time or another. It seems quite unlikely that either hydrocephalus or porencephaly could destroy the corpus callosum completely, although these two conditions have been reported to have produced partial agenesis or destruction of a partially developed corpus callosum.[11] This produces a corpus callosum which may be connected with all parts of the cortex, but is restricted in length and width, a condition which is comparable to the development at the fourth month of fetal life.

It is apparent, therefore, that there are many factors which can produce an agenesis of the corpus callosum.

REPORT OF CASES

The first 4 reports are cases of agenesis of the corpus callosum discovered at au-

topsy. They are included in this series because of the associated anomalies.

Case I. V. A. F., three-week old male infant who entered the hospital with difficulty in breathing. There was a harelip and cleft palate. The cleft palate was occupied by a soft, granular tumor mass with a mosaic surface and was thought to represent an hemangioma. After four days' hospitalization the child died.

Autopsy (A-41-303) demonstrated: Agenesis of corpus callosum, apparently complete; hydrocephalus of the lateral and third ventricles with complete atresis of the aqueduct; incomplete development of the fourth ventricle. The tumor mass in the nasopharynx was attached by a stalk to the hypophysis. It extended through the cribriform plate into the nasopharynx where it measured 4 by 2.5 by 1.0 cm. Histologically, it consisted of glial tissue containing primitive mesenchymal tissue, skin appendages, squamous epithelium, respiratory epithelium, cartilage and mucous glands.

Another interesting finding was the section from the frontal lobes which showed retardation in migration of neurones so that the structures seen represented the brain tissue of a six months' fetus. The neurones around the aqueduct, however, were normal.

Comment. This was a case of complete agenesis of the corpus callosum with a teratoma arising from the hypophysis and extending into the nasopharynx. In addition, there was an atresia of the aqueduct with incomplete development of the fourth ventricle. A cleft palate and harelip were associated anomalies.

Case II. J. A., male, aged fifty-two, entered the hospital in October, 1939, for respiratory complaints. He was a successful salesman who had no convulsions, neurologic abnormalities or mental aberrations.

Autopsy (A-39-308) showed a partial agenesis of the corpus callosum with only the anterior tip remaining. Just posterior to the genu was a vertical slit which involved the major portion of the corpus callosum. The fibers from both sides came up to this area and then broke off abruptly. The defect measured 3 by 7 mm. The septum pellucidum had a cavity measuring 0.5 by 2.0 cm. The left lateral wall of the cavity communicated with the left lateral ventricle, but the right did not. The third ventricle was normal in size, but elevated. The posterior horns were normal in size also. Histologic sections were reported as normal.

Comment. This was a case of partial agenesis with a small cavum septum pellucidum communicating with the left lateral ventricle only. No dilatation of the posterior horns of the lateral ventricles was demonstrated. Clinically, the patient had no mental or neurologic deficits.

Case III. F. C., a male, aged sixty-one, entered the hospital for intestinal obstruction. He died five days postoperatively. This man had no convulsions, physical or mental abnormalities, although he reached only the third grade in school.

Autopsy (A-39-252) revealed patency of the appendiceal stump; complete agenesis of the corpus callosum with absent septum pellucidum; dilatation of the posterior horns of the

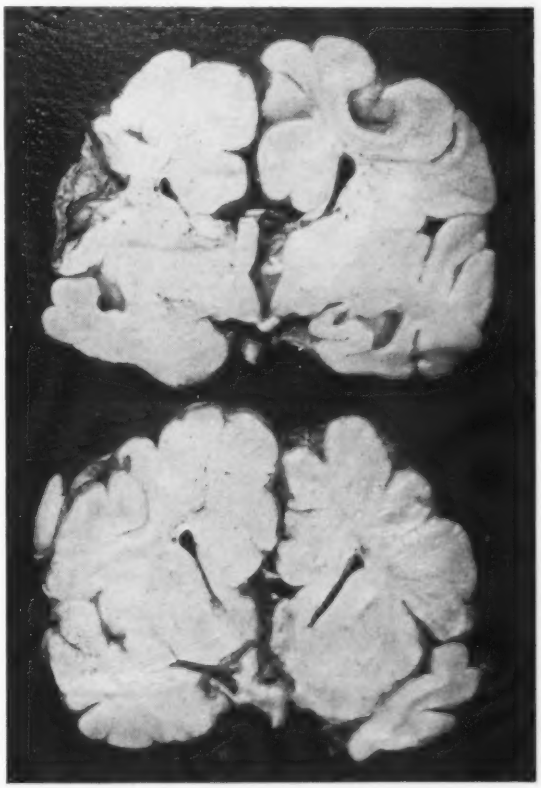


Fig. 1. Case IV. Section of brain showing the typical findings of agenesis of the corpus callosum. Each side of the section has been photographed.

lateral ventricles of extreme degree, leaving only a rim of tissue medially in both occipital lobes. The fourth ventricle and aqueduct were normal.

Comment. This was a case of complete agenesis with considerable dilatation of the posterior horns of the lateral ventricles.

CASE IV. D.P., an infant four days old, was admitted for multiple congenital anomalies including harelip, cleft palate, bilateral club feet. The child died suddenly due to aspiration of her formula.

Autopsy (A-50-266) demonstrated complete agenesis of the corpus callosum and septum pellucidum, dilatation of the posterior horns of the lateral ventricles and a grossly small cerebellum. Histologically, the cerebellum appeared normal and did not differ from a grossly normal cerebellum in a two week old infant whose central nervous system was entirely normal. Figure 1 demonstrates the section of brain best showing the agenesis of the corpus callosum.

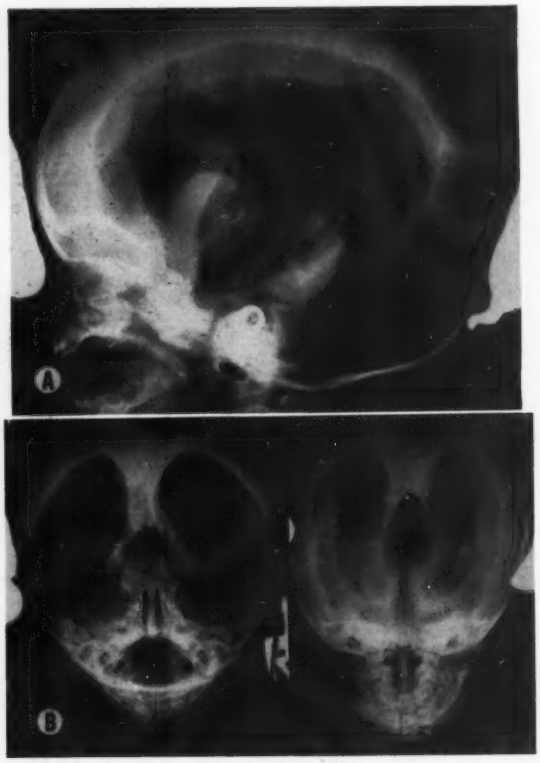


FIG. 2. Case v. Ventriculograms demonstrating in (*A*) (right lateral view) the hydrocephalus, the elevated third ventricle and the extreme enlargement of the posterior fossa with elevation of the tentorium. (*B*) (posteroanterior on left, anteroposterior on right) demonstrates the dilated lateral ventricles, the elevated third ventricle and the large amount of air in the posterior fossa.

Comment. This demonstrates a complete agenesis of the corpus callosum, septum pellucidum and the usually associated dilatation of the posterior horns of the lateral ventricles. In addition, the very interesting finding of a grossly small cerebellum with normal histology indicates that cerebellar hypoplasia was present.

The following 8 cases were diagnosed by means of air introduced either directly into the ventricles through burr holes, or by spinal subarachnoid introduction of air. Except for one case diagnosed in 1940 they represent the cases seen here since 1948 when all pediatric cases referred to this hospital for convulsions, mental deficiency or neurological deficits were subjected to air studies in the course of their workup.

CASE V. M. V., born on April 5, 1950, was seen in this hospital at the age of six days because of an enlarged head. Birth weight was $6\frac{1}{2}$ pounds. The gestation was normal, but the labor was prolonged in the second stage. Low forceps were used. The baby cried spontaneously and had normal respirations. Feeding was poor throughout her entire life. The head circumference at delivery was 39.3 cm.

Physical examination revealed a head circumference of 40.5 cm. Weight 6 pounds 1 ounce. Height $19\frac{3}{4}$ inches. The head was grossly enlarged with a tense, slightly bulging anterior fontanelle. The frontal bone bulged anteriorly. The only other findings of interest were bilateral lachrymal duct obstructions and a pilonidal sinus tract over the lower sacrum.

On April 11 a subdural aspiration was carried out, but no effusions were found. On April 19, 1950, the head circumference had enlarged to 42.5 cm. On April 20, 1950, at the age of fifteen days, a right anterior ventricular tap was done with removal of 215 cc. of fluid. This was replaced with air.

Ventriculograms are shown in Figure 2, *A* and *B*. These demonstrate the findings of a complete agenesis of the corpus callosum with considerable hydrocephalus involving the entire visualized ventricular system. The separation of the lateral ventricles in spite of the extreme hydrocephalus is noteworthy and

significant. A large, irregular collection of air is seen beneath the tentorium. The right lateral view demonstrates the elevated third ventricle, producing a comma-shaped area of radiolucency between the anterior portions of the lateral ventricles. Note the extensive amount of air in the cisterna magna, indicating cerebellar anomaly or atrophy with elevation of the usual site of the tentorium. Although our antemortem diagnosis was: agenesis of the corpus callosum with an associated cerebellar anomaly, we did not make a diagnosis of an atresia of the foramens of Luschka and Magendie. The findings are typical of this malformation, however.

Postmortem studies at the age of thirty-five days (A-50-167) revealed a complete agenesis of the corpus callosum. There was a cyst measuring 5 cm. in diameter filled with thin yellow fluid, located above the cerebellum but beneath the tentorium which was elevated. The cyst was lined with degenerating brain tissue and was continuous with the fourth ventricle. No attempt was made to demonstrate the closure or patency of the foramens of Luschka and Magendie. There was, however, a failure of development of the vermis of the cerebellum and the two cerebellar hemispheres. These were connected by a small bridge of brain tissue anteriorly. The cerebellar hemispheres were small and measured 2 cm. in diameter. Histologically the cortex of the cerebellar hemispheres showed a normal but attenuated architecture. (A similar finding was present in Case IV.)

Comment. The diagnosis of agenesis of the corpus callosum and cerebellar anomaly was made at the age of fifteen days in this patient. Autopsy confirmation was obtained at the age of thirty-five days and demonstrated, in addition to the agenesis of the corpus callosum, an agenesis of the vermis, hypoplasia of the cerebellar hemispheres and a cyst in the posterior fossa communicating with the fourth ventricle. This case is one of atresia of the foramens of Luschka and Magendie associated with an agenesis of the corpus callosum.

Case VI. D. R., born April 7, 1949, was seen in this hospital on December 24, 1949, at the age of eight months. His birth weight was 9½ pounds. No difficult labor was present. The mother was told that there was some difficulty during the ten or eleven days that the infant was kept in the hospital. Apparently there was considerable vomiting which persisted even after he went home. Various formulas were given but vomiting continued. The child appeared normal to the mother until he was three and one-half months old, at which time he made no progress in his ability to grasp

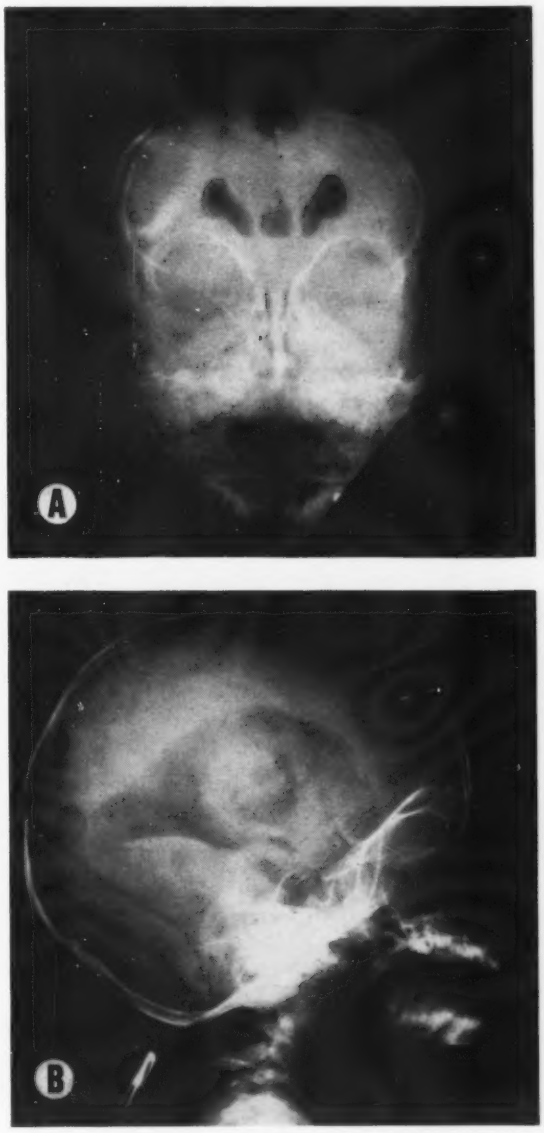


Fig. 3. Case VI. Ventriculograms demonstrating in (*A*) (anteroposterior view) and (*B*) (left lateral view) the agenesis of the corpus callosum with indentation of the superior border of the third ventricle by the falx. Note the absent posterior arch and spinous process of the atlas.

objects or to turn over. At present he cannot sit and has not reached for objects, but the parents believe that he can see.

Two teeth have erupted. No immunizations had been given to this child. He had measles at one and one-half months and whooping cough at six and one-half months.

Physical examination showed the child to be below average in length, weight and head circumference with the following values: head circumference 43 cm., weight 5,550 grams and height 25½ inches. Neurologically there was no deficit.

Attempts were made to introduce air into the spinal subarachnoid space but were unsuccessful. Therefore, ventriculograms were done at which time it was evident that there was bilateral cortical atrophy, and increase in the subarachnoid fluid. Cortical biopsies were done and were reported later as being normal.

Films taken following introduction of air into the lateral ventricles are shown in Figure 3, *A* and *B*. The findings are those of an agenesis of the corpus callosum. Note the wide separation of the lateral ventricles; concave mesial portions of part 3; elevation of the third ventricle, the superior border of which is indented by the falx; the dilatation of the posterior horns; and the absence of the posterior arch and spinous process of the atlas. The absence of air in the posterior fossa is not significant since no effort was made to fill this region.

Comment. This represents a case of complete agenesis of the corpus callosum. An associated anomaly was an absent posterior arch and spinous process of the atlas.

Case vii. D. C., birth date October 17, 1948. Patient was seen at the State University of Iowa Hospital February 13, 1950, at the age of sixteen months because of convulsions. The delivery was normal and the mother's pregnancy was normal aside from a kidney infection two weeks prior to delivery. The baby was said to be active, alert and healthy until the age of four months, at which time she was reported to have fallen from a kitchen table to the floor. She was not unconscious and had no visible trauma, yet one week later the child jerked and startled at sudden noises, seemed quieter and less interested in play. At the age of five months she began to have convulsions starting with a sudden cry, turning of head and eyes to the left with tonic contractions of the entire left side. These occurred several times a week, frequently during sleep. She never has been able to sit, crawl, or stand.

The positive physical findings were: head 44 cm., asymmetrical, moves head from side to side, poor use of paretic extremities, mental retardation and exotropia.

Electroencephalogram 14 lead reported: This record, run mostly when the child was asleep, shows focal spikes, intermittently, in the right motor area. A peculiar sleep spindle, of "sharp" character, appeared bilaterally, almost always greater in the left (suppressed in right?). Impression: Abnormal electroencephalogram, focal (right sided.)

Ventriculograms are shown in Figure 4, *A*, *B*, *C*. These demonstrate an agenesis of the corpus callosum. The appearance is strikingly similar to Case v. Note the dilated parts 1, 2 and 3 of the lateral ventricles and the small posterior and temporal horns; the elevated and dilated third ventricle; the large cisterna magna and cisterna pontis. The lateral view with the brain down demonstrates the enlarged cisterna magna and small cerebellum.

Comment. The findings are those of an agenesis of the corpus callosum, probably complete, although there appears to be a small remnant of it anteriorly. The increased amount of air in the cisterna magna indicates an anomaly in the development of the cerebellum associated with a decrease in its size.

Case viii. B. S., birth date August 21, 1948. She was seen here on July 12, 1949, at the age of eleven months and again on December 3, 1949, at sixteen months. Her birth weight was 6¾ pounds. The mother had severe hyperemesis during the entire pregnancy. No immunizations had been given. The child had convulsions since the age of two months, starting as a jerking movement of the arms and legs with flexion, followed by flexion of the torso. Whereas initially they occurred two to three times a day, they have occurred as many as twenty times a day. At the age of five months she began to have a different type of convulsion in which she elevates the left arm, turns on her left side and emits a strange sound with the mouth open. The baby is blind and cannot sit alone.

Examinations revealed a bilateral microph-

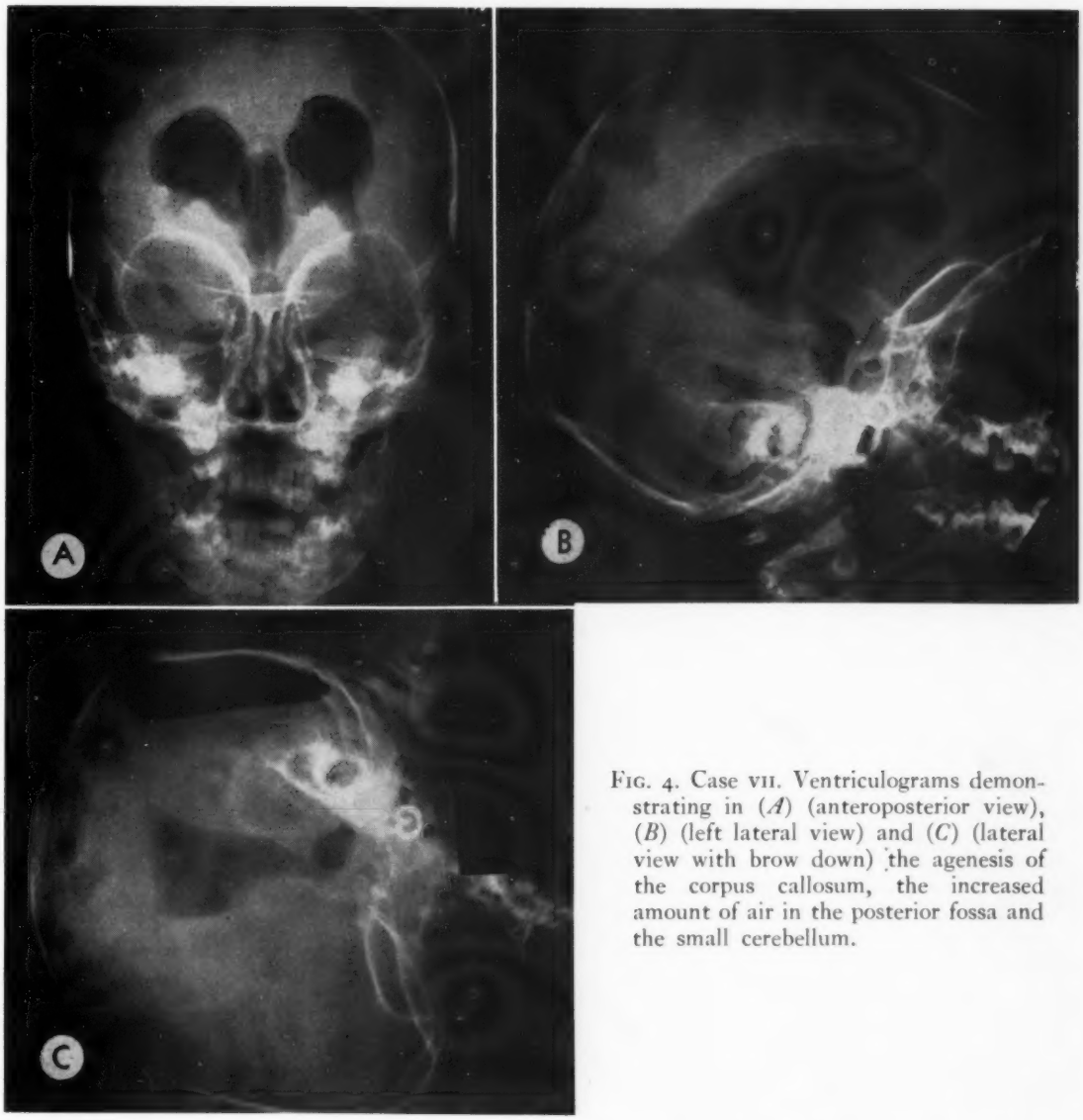


Fig. 4. Case VII. Ventriculograms demonstrating in (*A*) (anteroposterior view), (*B*) (left lateral view) and (*C*) (lateral view with brow down) the agenesis of the corpus callosum, the increased amount of air in the posterior fossa and the small cerebellum.

thalmia; lenticular opacity on the right; and a left vitreous mass containing yellowish-gray moderately refractile crystals, type undetermined. At the time of ventriculography bilateral cortical atrophy, more severe on the right, was seen.

Ventriculograms are shown in Figure 5, *A* and *B*. These demonstrate an agenesis of the corpus callosum. Note the typical deformity of the left lateral ventricle; the elevated third ventricle which is rounded superiorly and obscured by the mesial convolutions containing air; the cortical atrophy on the right; the enlarged right ventricle; and the small amount of air in the cisterna magna.

Comment. The findings are those of an agenesis of the corpus callosum, probably partial in degree, since the anterior portion of the third ventricle appears indented. This suggests the presence of a small remnant in this location. There is an associated cortical atrophy, more marked on the right, and dilatation of the entire right lateral ventricle.

Case IX. J. H., birth date September 19, 1948. She was first seen here at the age of fourteen months. Mother's pregnancy was normal. Normal delivery was carried out with low forceps applied to the head. Developmentally the

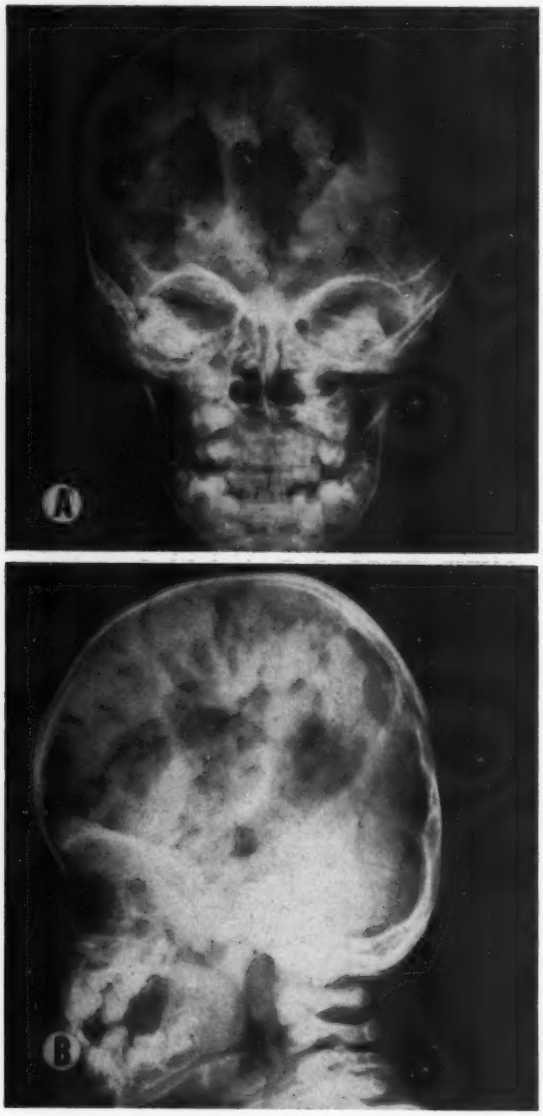


FIG. 5. Case VIII. Ventriculograms demonstrating in (*A*) (anteroposterior view) and (*B*) (right lateral view) the agenesis of the corpus callosum, the extreme cortical atrophy with visualization of the mesial convolutions which partially obscure the third ventricular shadow. Note the small amount of air in the cisterna magna.

child was slow, only being able to sit alone at the age of thirteen months. The child had been immunized.

The child was well until eleven months of age at which time she had her first convulsion characterized by turning of the head to the left with the eyes rolled to the left. This was followed by a generalized convulsion of all extremities with extension predominantly of the right leg. At the age of thirteen months she had another convulsion. At fourteen months the third convulsion occurred.

Physical examination was negative except for left internal strabismus. Electroencephalogram showed focal spike activity in the left posterior quadrant and a suppression of sleep spindle activity over the left central region. Re-examination on February 20, 1950, showed a mentally retarded child who showed spontaneous movement of all extremities without focal neurological phenomena.

Pneumoencephalograms are shown in Figure 6, *A* and *B*. The films demonstrate the difficulty in deciding whether an agenesis of the corpus callosum is present when a cyst or mass in the septum pellucidum is present. Note the symmetrically dilated ventricular system with separation of part 3 on each side and the slight concavity medially; the mass in the midline anteriorly producing the defect in the air-filled ventricles; the lack of elevation of the third ventricle; the presence of the massa intermedia; the abnormal appearing fourth ventricle which is rounded, dilated and which has lost its normal configuration; the increase in size of the cisterna magna; and the cortical atrophy.

Comment. The findings are confusing but indicate the presence of a mass in the midline of the frontal horns which may be either a cyst of the septum pellucidum or a tumor of a type undetermined. The lateral displacement of the lateral ventricles as seen in all of the films, together with the slightly concave mesial borders of part 3 of the lateral ventricles, indicates a partial agenesis of the corpus callosum. The mass does not permit the elevation of the third ventricle. Associated anomalies found in this case were the abnormal appearing fourth ventricle, cortical atrophy, and cerebellar anomaly. The latter finding is based upon the large amount of air in the cisterna magna.

CASE X. T. S., twenty-six years old, was first seen in this hospital in 1940 because of convulsions which started at the age of four years. No history was available as to the type of convulsions. They, however, disappeared in 1937. At this time they recurred every two months with unconsciousness during part or all of the

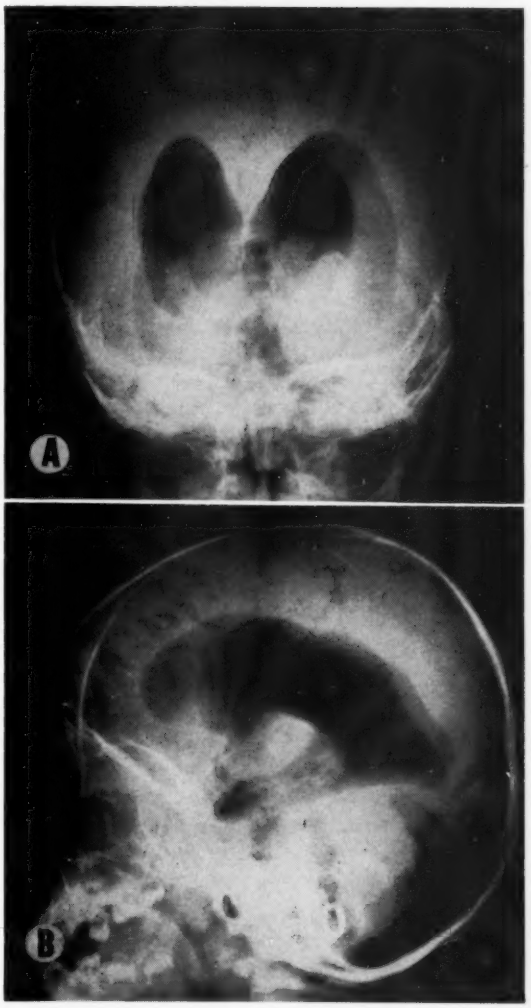


Fig. 6. Case IX. Pneumoencephalograms demonstrating in (*A*) (anteroposterior view) and (*B*) (left lateral view) the separation of parts 3 of each lateral ventricle which is dilated. Note the mass in the midline anteriorly producing the filling defect in the air-filled ventricles. There is no elevation of the third ventricle which appears normal and in which the massa intermedia is visualized. The amount of air in the posterior fossa is significantly greater than normal. See text for discussion of these findings.

attack and were generalized. She has always had a small right arm and leg. The patient had a tenth grade education, was married and had one normal child.

Physical examination showed slight but definite hemiplegia and hemiatrophy on the right. The electroencephalogram showed abnormal activity over the right occiput.

Pneumoencephalograms are shown in Figure 7, *A* and *B*. The films demonstrate an agenesis of the corpus callosum with porencephaly. Note the typical deformity of the right lateral ventricle; the elevated third ventricle; the large, irregular collection of air on the left in the mid-parietal area; the dilated left posterior horn; the cortical atrophy in the right frontal and

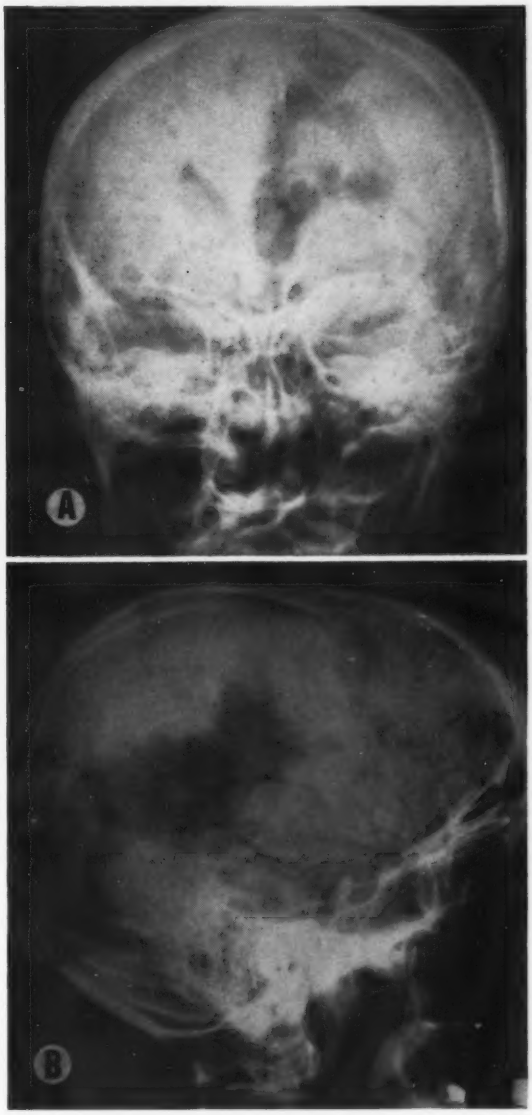


Fig. 7. Case X. Pneumoencephalograms demonstrating in (*A*) (anteroposterior view) and (*B*) (right lateral view) the agenesis of the corpus callosum and the porencephalic cavity which is air filled and is located in the left mid-parietal area. Note the asymmetry of the skull and the greater development of the frontal sinus on the left indicative of cerebral malformation.

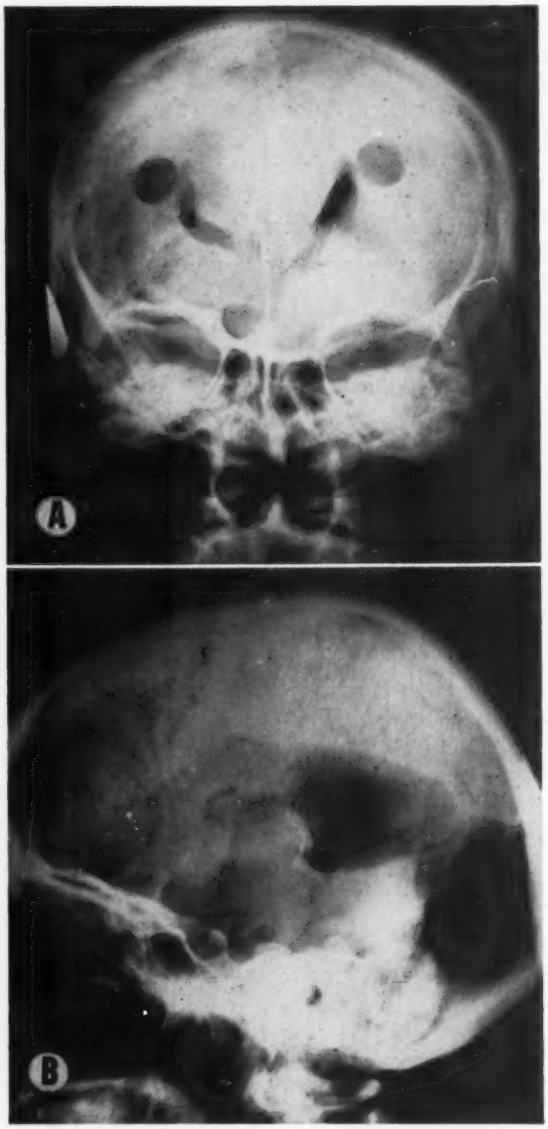


Fig. 8. Case xi. Pneumoencephalograms demonstrating in (*A*) (anteroposterior view) and (*B*) (right lateral view) the typical findings in agenesis of the corpus callosum. Note the large amount of air in the posterior fossa.

left temporal regions; and the asymmetry of the skull and frontal sinuses which in themselves are indicative of abnormal development of the left cerebral hemisphere.

Comment. This case represents an agenesis of the corpus callosum, but whether it is complete or partial cannot be definitely established in the light of the poor filling of the third ventricle as viewed in the lateral projections. Associated anomalies are seen in the cortical atrophy, and the porencephaly in the left mid-parietal area. One could suspect the left cerebral maldevelopment on the basis of the asymmetry of the calvarium and of the frontal sinuses.

Case xi. A. A., thirty-eight years old, was first seen at this hospital in November, 1949, and again on January 22, 1950, for left-sided convulsions of thirteen years' duration. Each convulsion was preceded by an aura of sucking and numbness in the left extremities. Loss of consciousness was present. The convulsions occurred two to three times a week.

Physical examination revealed a nystagmus to the left on extreme gaze, but normal optic discs. The left upper and lower extremities were smaller than the right. Athetoid movements of the left fingers when moving the left upper extremity were present. All reflexes were physiological, however. Electroencephalogram revealed a focus of slow wave in the right frontotemporal region. Psychometric examination showed an original intellectual endowment of dull average intelligence with evidence of acquired impairment of significant degree.

The pneumoencephalograms are shown in Figure 8, *A* and *B*. These films demonstrate the typical findings of agenesis of the corpus callosum including the dilatation of the posterior horns and elevation of the third ventricle. Note the separated lateral ventricles with concave, pointed part 3 of each lateral ventricle; the dilated posterior horns; the large amount of air in the basal cisternae and in the cisterna magna. Cerebral angiograms are shown in Figure 9, *A* and *B*. They demonstrate the anomalous position of the right anterior cerebral and middle cerebral arteries due to the abscence of the corpus callosum.

Comment. This case represents a complete agenesis of the corpus callosum. The pneumoencephalographic findings are confirmed by cerebral angiography. An associated finding was the presence of significant enlargement of the cisterna magna indicating the presence of a cerebellar anomaly.

Case xii. T. D., birth date June 30, 1947, The patient was seen at this hospital on April 20, 1949, at the age of twenty months because the head appeared larger than normal for his age, and because he appeared to have difficulty in holding his head erect.

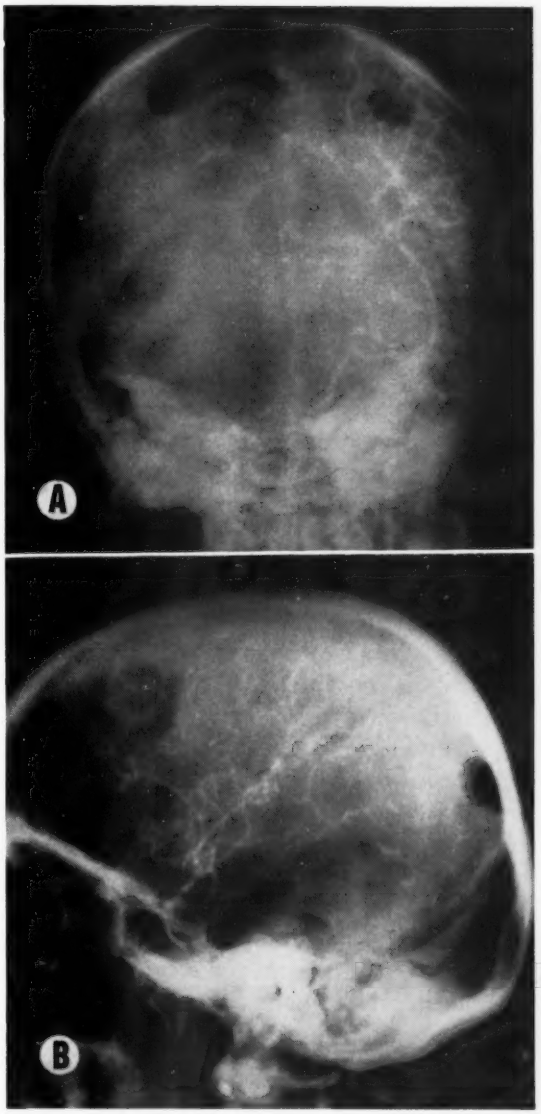


Fig. 9. Case xi. Cerebral angiograms demonstrating the anomalous position of the right anterior and middle cerebral arteries in agenesis of the corpus callosum.

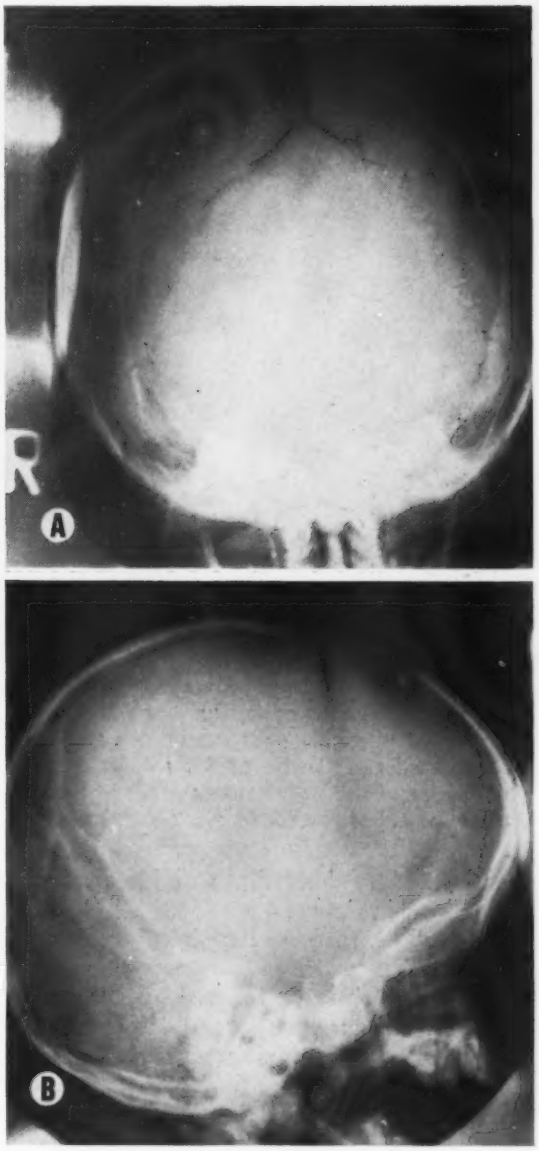


Fig. 10. Case xii. Routine skull films in anteroposterior and left lateral projection demonstrate the enlarged calvarium, and the failure of descent of the lateral dural sinuses which are present in the posterior parietal bones instead of being located in the occipital bone. This is typical of an atresia of the foramens of Luschka and Magendie.

Examination revealed a head size of 55.75 cm. No neurological deficit could be made out. Psychometric examination revealed some retardation.

Anteroposterior and lateral films of the skull are shown in Figure 10, *A* and *B*. These demonstrate considerable enlargement of the calvarium, but the significant finding is the presence of the lateral sinuses in the posterior portion of the parietal bone instead of being located in the occipital bone. Ventriculograms demonstrated the typical findings of a complete agenesis of the corpus callosum. The only film available for reproduction is shown in Figure 11. This demonstrates the agenesis of the corpus callosum. Note how the falx indents the superior aspect of the elevated third ventricle. There is also demonstrated considerable air in the posterior fossa which was seen to better advantage in the lateral views, but these have

Fig. 11. Case xii. Ventriculogram in anteroposterior projection demonstrating the agenesis of the corpus callosum. Note the indentation of the superior border of the elevated third ventricle by the falx, and the large amount of air in the posterior fossa. See text for further discussion.

been lost. All of the findings are identical with those shown in Case v.

On April 29, 1949, a suboccipital craniotomy was done. There was moderate tension of the dura mater which was relieved by ventricular puncture. The dura was opened exposing a very large membrane occupying most of the visible portion of the operative field. It was felt that this was an enlargement of the cisterna magna. Upon incision of this, approximately 2.5 ounces of cerebrospinal fluid was evacuated. The fourth ventricle presented at the bottom of the operative field. It was blunt in its delineation and appeared to be very much like a medullary plate. When the membrane was properly dissected, it was seen that there was a large foramen of Magendie at the midline of the inferiormost portion of the operative field. The cerebellum was inspected and it was then established that, while the patient had fairly normal appearing cerebellar hemispheres, there was no evidence of a vermis at any point. A complete absence of the corpus callosum was established. The aqueduct of Sylvius was large and admitted a No. 12 catheter. It was possible to palpate the midline of the vault of the skull. Here only a small ridge, not more than $\frac{1}{4}$ inch in height, represented the remnant of the falx cerebri.

Comment. This case represents one of complete agenesis of the corpus callosum and, in my opinion, represents an atresia of the foramens of Luschka and Magendie similar to the cases reported by Taggart and Walker,[24] and by Sahs.[19] The cerebellar anomaly associated with the above atresia was present in this case. Roentgenograms of the skull demonstrated the abnormal position of the lateral sinuses and this finding should have suggested to us the probability of an atresia of the foramens of Luschka and Magendie and cerebellar anomaly.

DISCUSSION

Agenesis of the corpus callosum usually offers no problem in diagnosis from the roentgenographic standpoint, especially when it is complete. The difficulties in diagnosis are seen in cases of partial agenesis, especially of the splenium, and in cases of communicating cysts of the septum pellucidum. Careful study of the films will, however, indicate not only the complete or partial absence of the corpus callosum, but also the site and extent of the defect. Careful study of the films will also make it possible to exclude the presence of a communicating cyst of the septum pellucidum. There are, however, sufficient deviations from the usually expected picture of agenesis of the corpus callosum that considerable doubt may exist in the mind of the roentgenologist as to which lesion is present in a specific case.

The frequent demonstration at encephalography or ventriculography of enlargement of the cisterna magna in this series of cases of agenesis of the corpus callosum has been impressive. Aside from Guttman's[11] description of considerable enlargement of the cisterna magna, no further mention of its occurrence has been made in the literature. Murphy and Arana[16] and Uzman[26] have described the pneumoencephalographic findings in cerebellar atrophy, but not in conjunction with agenesis of the corpus callosum. Sahs[19] de-

scribed in detail a case with an anomaly of the cerebellar vermis having identical findings in the posterior fossa as Cases v and xii of this series. His case, however, did not have an associated agenesis of the corpus callosum. Taggart and Walker[24] have given an excellent embryological explanation for these findings. According to them, an atresia of the foramens of Luschka and Magendie is the basic defect. This produces an enlargement of the fourth ventricle which fills the greater part of the posterior fossa. This in turn interferes not only with the development of the cerebellum, but also prevents the migration of the transverse and confluent sinuses. These sinuses retain their fetal position in the posterior parietal bone instead of migrating to the occipital bone. Figure 10 demonstrates the presence of the transverse sinuses in the posterior parietal bones. This finding alone should have indicated to us the underlying pathology and its cause. The finding of a foramen of Magendie at the time of operation in this case does not exclude an atresia. The foramen could have been atretic beyond the site visualized by the surgeon.

Identical findings were present in Case v and will not be further discussed.

None of the remaining cases demonstrated the findings of an atresia of the foramens of Luschka and Magendie, but there were 3 cases showing enlargement of the cisterna magna. This, in my opinion, represents an anomaly of the cerebellum. It is not possible to state whether the anomaly consists of agenesis, hypoplasia, atrophy, or abnormal development. Hypoplasia in terms of size of the cerebellum may be present without histological abnormality. This was demonstrated in Case iv, autopsy series.

Evidence has been presented that cerebellar anomalies are not infrequently found in cases of agenesis of the corpus callosum, particularly if one looks for them. Further study, both roentgenographically and surgically (at operation or at autopsy), will give us a more comprehensive understanding of the incidence and types of cerebellar abnormalities associated with complete or partial agenesis of the corpus callosum.

SUMMARY

1. Twelve cases of agenesis of the corpus callosum have been presented with the clinical and roentgenographic findings. When electroencephalography or other special procedures were done, the findings were included. Four of the cases were discovered at autopsy. Eight cases were diagnosed during the life of the individual.

2. Two cases of atresia of the foramens of Luschka and Magendie associated with the agenesis of the corpus callosum are presented, together with the diagnostic criteria for its recognition on the routine skull examination.

3. Enlargement of the cisterna magna was demonstrated in five cases of this series and its significance is discussed.

4. Anomalies associated with the agenesis of the corpus callosum are tabulated below and consist of:

cleft palate and harelip, 2 cases
porencephaly, 1 case
teratoma arising from hypophysis, 1 case
abnormal fourth ventricle, 2 cases
atresia of aqueduct, 1 case
cortical atrophy, 4 cases
cavum septum pellucidum, 1 case
absence of posterior arch and spinous process of atlas, 1 case
lenticular opacities, microophthalmia, and optic atrophy, 1 case
unilateral atrophy of one side of body, 2 cases.

University Hospitals,
Iowa City, Iowa

REFERENCES

1. Amyot, R. Un cas d'agénésie du corps calleux diagnostic par la pneumo-encephalographie. *Union méd du Canada*, 1948, *77*, 667–669.
2. Bruce, A. On the absence of the corpus callosum in human brain with description of new case. *Brain*, 1890, *12*, 171.
3. Bunts, A. T., and Chaffee, J. S. Agenesis of corpus callosum with possible porencephaly; review of literature and report of case. *Arch. Neurol. & Psychiat.*, 1944, *51*, 35–53.
4. Charest, F. Agénésie du corps calleux. *J. de l'Hôtel-Dieu de Montréal*, 1945, *14*, 300–301.
5. Chusid, J. G., de Gutierrez-Mahoney, C. G.,

and Chaffee, J. S. Agenesis of corpus callosum; electroencephalographic study. *Arch. Neurol. & Psychiat.*, 1949, *62*, 840–846.

6. Davidoff, L. M., and Dyke, C. G. Agenesis of corpus callosum; its diagnosis by encephalography. Am. J. Roentgenol. & Rad. Therapy, 1934, *32*, 1–10. Abs. in *Tr. Am. Neurol. Assn.*, 1934, *60*, 181.
7. Echternacht, A. P., and Campbell, J. A. Mid-line anomalies of the brain; their diagnosis by pneumoencephalography. *Radiology*, 1946, *46*, 119–131.
8. Eshbaugh, D. Relation of changes in the brain to those in skull of Crouzon's and similar diseases, with report of case. *J. Neuropath. & Exper. Neurol.*, 1948, *7*, 328–343.
9. Foster, S. E., and Windholz, F. Radiological studies in rare but typical cerebral malformations; encephalographic findings in cerebral hemiagenesis, absence of corpus callosum and absence of septum pellucidum. *Stanford M. Bull.*, 1948, *6*, 395–406.
10. Friedman, M., and Cohen, P. Agenesis of corpus callosum as possible sequel to maternal rubella during pregnancy. *Am. J. Dis. Child.*, 1947, *73*, 178–185.
11. Guttmann, L. Quoted by Davidoff and Dyke.[6]
12. Hyndman, O. R., and Penfield, W. Agenesis of corpus callosum; its recognition by ventriculography. *Tr. Am. Neurol. Assn.*, 1934, *60*, 182–184. Also, *Arch. Neurol. & Psychiat.*, 1937, *37*, 1251–1270.
13. Josephy, H. Congenital agyria and defect of corpus callosum. *J. Neuropath. & Exper. Neurol.*, 1944, *3*, 63–68.
14. Kirschbaum, W. R. Agenesis of corpus callosum and associated malformations. *J. Neuropath. & Exper. Neurol.*, 1947, *6*, 78–94.
15. Marburg, O. So-called agenesia of corpus callosum (callosal defect); anterior cerebral dysraphism. *Arch. Neurol. & Psychiat.*, 1949, *61*, 297–312.
16. Murphy, J. P., and Arana, Roman. The pneumoencephalogram of cerebellar atrophy. Am. J. Roentgenol. & Rad. Therapy, 1947, *57*, 545–555.
17. Pospiech, K. H. Cited by Savitsky and Spinelli.[20]
18. Reil, J. Cited by Davidoff and Dyke.[6]
19. Sahs, A. L., Congenital anomaly of cerebellar vermis. *Arch. Path.*, 1941, *32*, 52–63.
20. Savitsky, E., and Spinelli, V. A. Agenesis of corpus callosum in infancy; clinical and roentgenologic aspects. *Am. J. Dis. Child.*, 1948, *76*, 109–115.
21. Sheinmel, A., and Lawrence, L. R. Agenesis of corpus callosum; lipoma of corpus callosum; their roentgen recognition and differentiation. *Radiology*, 1951, *57*, 15–24.
22. Stuhl, L., and Morice, MM. Etude radiologique et electroencephalographique de 9 cas de malformations ventriculaires par agénésie de commissures interhemispheriques; considerations cliniques. *Rev. neurol.*, 1948, *80*, 701–702.
23. Svaty, J., and Masek, R. Agenesia of corpus callosum and septum pellucidum with porencephaly of cerebellum. *Časop. lék. česk.*, 1950, *89*, 1171–1177.*
24. Taggart, J. K., Jr., and Walker, A. E. Congenital atresia of foramens of Luschka and Magendie. *Arch. Neurol. & Psychiat.*, 1942, *48*, 583–612.
25. Tunestam, N. Agenesi av corpus callosum; tva fall has barn. *Nord. med.*, 1950, *44*, 1287–1288.
26. Uzman, L. Pneumoencephalography in diagnosis of cerebellar atrophies. Am. J. Roentgenol. & Rad. Therapy, 1948, *60*, 293–302.

DISCUSSION†

Dr. Eugene P. Pendergrass, Philadelphia, Penna. Dr. Van Epps has presented a very interesting paper on agenesis of the corpus callosum. I personally did not know anything about this condition until it was called to my attention by the late Dr. Cornelius Dyke. Since then, I have seen a number of cases and I am sure that some of the patients with partial agenesis have passed unrecognized. This is particularly true when one is dealing with concomitant congenital malformations. The diagnosis of agenesis of the corpus callosum is very easy in certain cases where there is great separation of the lateral ventricles, elevation of the third ventricle, and so forth; but when some of the typical signs are missing the diagnosis is more difficult.

Midline tumors can produce ventricular deformities that look very much like agenesis of the corpus callosum and should therefore be considered in the differential diagnosis. In fact, tumors such as lipomas may be associated with agenesis of the corpus callosum. One might even suggest the diagnosis, if on the conventional roentgenograms one sees a zone of decreased density in the midline just above the pituitary fossa. I have seen 2 such cases.

I am glad that Dr. Van Epps included cerebral angiography in one of his cases. As more experience and opportunities are provided for cerebral angiography in patients with agenesis of the corpus callosum, we will probably find additional explanations for some of the concomitant malformations.

* This journal not available and read by title only, but is included because of the finding of cerebellar porencephaly.

† See also further discussion on page 89.

Vol. 70, No. 1

CEREBRAL ANGIOGRAPHY

FUNDAMENTALS IN ANATOMY AND PHYSIOLOGY*

By PHILIP J. HODES, M.D., FRANCISCO CAMPOY, M.D., HELEN E. RIGGS, M.D., *and* PAUL BLY, M.D.

PHILADELPHIA, PENNSYLVANIA

CEREBRAL angiography is being used more commonly every day throughout the world. Employed for over twenty years in Europe, the procedure was not commonly accepted in this country until relatively recently. With popularization of this diagnostic modality has come new and added responsibility for radiologists. The procedure that once was used to demonstrate gross vascular deformities is now being used for the recognition of the earliest manifestations of cerebral disease and disordered physiology. It becomes mandatory, therefore, that radiologists interested in neuroroentgenology become familiar with anatomical and physiological fundamentals.

The purpose of the present report is to review our postmortem findings in over 110 brains injected with radiopaque material and roentgenographed, which were subsequently carefully dissected for anatomical detail. In addition, we shall attempt to summarize some of the more recent contributions to the field of cerebral physiology and cerebral metabolism.

ANATOMICAL CONSIDERATIONS

After experimenting with various media, ordinary barium suspended in formalin was decided upon as the contrast medium of choice. The solution was injected into an internal carotid artery, or a vertebral artery, under direct visualization after careful neck dissection. In many instances, portions of the circle of Willis were ligated for better visualization of selected portions of the brain. Roentgenograms were then made at the autopsy table in various projections, depending upon the requirements of the specific experiment. The cranial vault was then carefully removed, the brain dissected free, and the gross anatomic findings recorded. In some instances the vessels of the brain were dissected in the fresh specimen, where they were most easily followed. Many more brains were allowed to harden in formalin before they were again roentgenographed and dissected. Care was exercised always to prevent distortion of the normal brain contour while the specimens were hardening.

Our brain dissections led to no startling discoveries. The gross anatomy of cerebral angiography having been worked out previously, we expected to find nothing new. Thus, we shall make no attempt here to review the normal roentgen anatomy of the cerebral circulation which has been done many times before by others as well as ourselves.[3,4,6,7,11] What troubled us clinically, and what we hoped to clarify, were the vascular patterns we call "anatomical variants." We wished also to determine how closely the vessels of each half of the brain mirrored each other. We wanted to see how much improper positioning of the head influenced normal vascular patterns on roentgen examination. And finally, we wondered just what one would find in routine postmortem material.

The most interesting anatomical findings concerned the circle of Willis. Whereas the entire circle is usually not demonstrated in cerebral angiography, the fact that it varied remarkably seemed important because of its function as a constant, albeit irregular, anastomosis between the carotid and vertebral systems. This had long been known to one of us (H.E.R.)[13,14] who had

* From the Department of Radiology, Hospital of the University of Pennsylvania, and the Laboratories, Philadelphia General Hospital, Division of Neuropathology, Philadelphia, Pennsylvania. Presented at the Fifty-second Annual Meeting, American Roentgen Ray Society, Washington, D. C., Sept. 25–28, 1951.

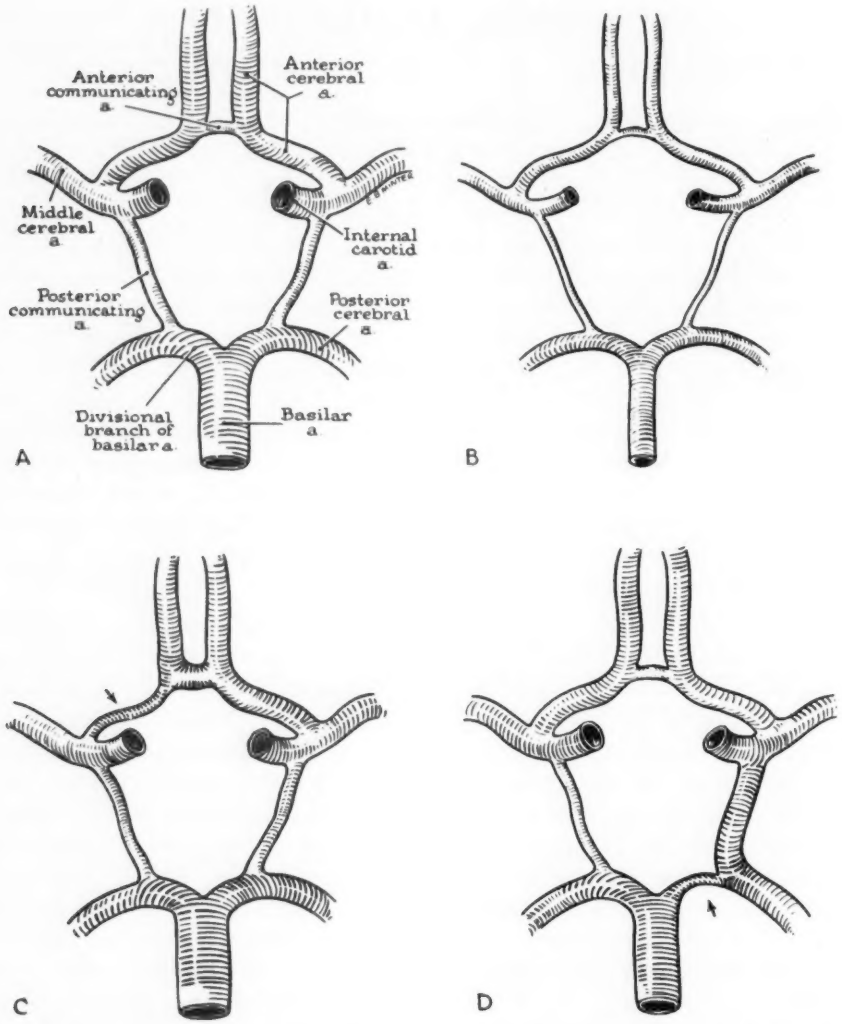


FIG. 1. Forms of circle of Willis found at autopsy and their incidence. (*A*) Group I, 18 per cent; (*B*) Group II, 6 per cent; (*C*) Group III, 25 per cent; (*D*) Group IV, 16 per cent.

dissected thousands of brains previously, and had come to recognize the so-called "normally formed" circle to be relatively uncommon, as did Adachi[1] and Padget.[12]

In 1936 one of us (H.E.R.)[13,14] analyzed statistically the various forms of circle of Willis observed in 1,647 autopsies. Because they seemed to divide themselves into eight anatomic types, they were so classified.

Group I. In Group I were placed the classical "normally formed" circles of Willis described in textbooks. Of the 1,647 brains examined, the circle was considered "normal" in but 200 (18 per cent) (Fig. 1*A*).

Group II. In 102 cases (6 per cent) the circles seemed normally formed but hypoplastic (Fig. 1*B*).

Group III. This included the circles of Willis that revealed unilateral focal hypoplasia of an internal carotid and/or anterior cerebral artery. This was the most common type and was observed in 407 brains (25 per cent) (Fig. 1*C*).

Group IV. In Group IV were placed circles with unilateral hypoplasia of a divisional branch of the basilar artery, which usually was associated with partial or complete internal carotid origin of the homolateral posterior cerebral artery. The latter was observed in 274 specimens (16 per cent) (Fig. 1*D*).

Group V. Circles of Willis revealing hypo-

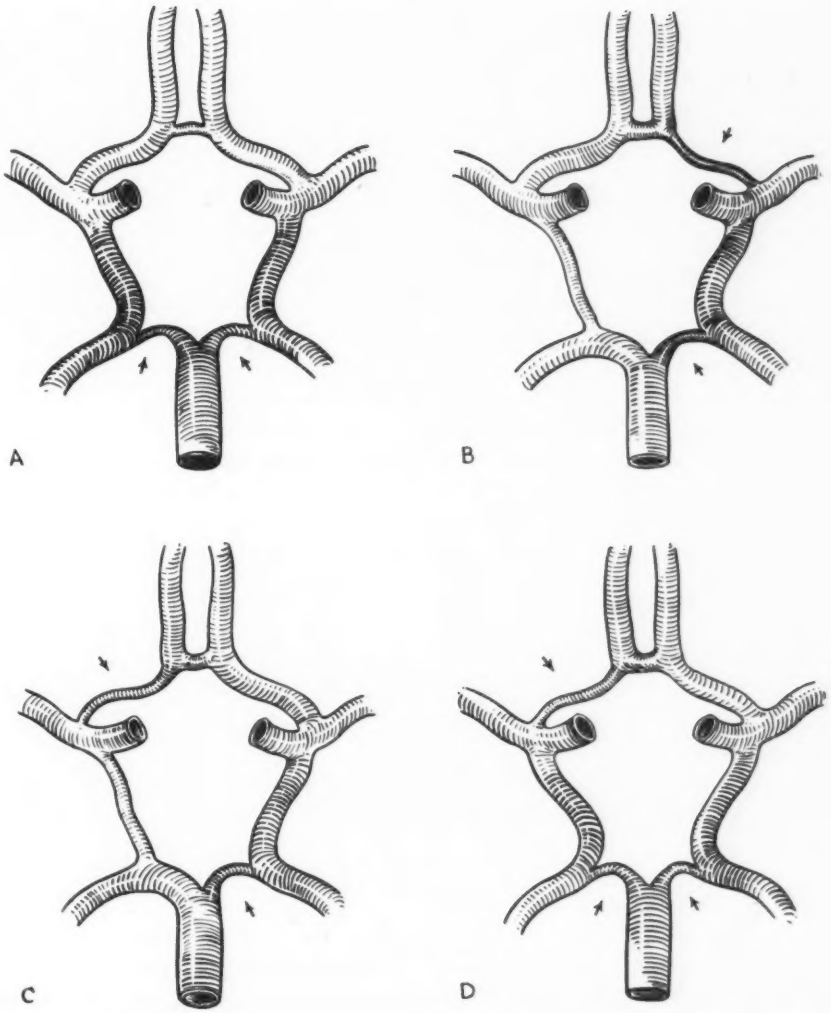


Fig. 2. Forms of circle of Willis found at autopsy and their incidence. (*A*) Group v, 11 per cent; (*B*) Group vi, 8 per cent; (*C*) Group vii, 8 per cent; (*D*) Group viii, 8 per cent.

plasia of both divisional branches of the basilar artery, associated with partial or complete internal carotid origin of both posterior cerebral arteries, were placed in this group. It included 182 individuals (11 per cent) (Fig. 2*A*).

Group VI. This group combined anatomical variants in the anterior and posterior portions of the circle of Willis on the same side. The latter revealed unilateral focal hypoplasia of an anterior artery, plus hypoplasia of a divisional branch of the basilar artery on the same side, coupled with partial or complete internal carotid origin of the posterior cerebral artery. This form of circle occurred 134 times (8 per cent) (Fig. 2*B*).

Group VII. This group revealed bilateral variants in the circle of Willis. In it were included examples of unilateral focal hypoplasia of an anterior division which also revealed hypoplasia of a contralateral divisional branch of the basilar artery, which was associated with partial or complete internal carotid origin of the posterior cerebral artery. One hundred and thirty-three circles of Willis fell in this classification (8 per cent) (Fig. 2*C*).

Group VIII. There were 125 circles of Willis in Group viii (8 per cent). It included circles with unilateral focal hypoplasia of anterior division, plus bilateral hypoplasia of the divisional branches of the basilar artery, with the usual associated partial or complete internal carotid origin of both posterior cerebral arteries (Fig. 2*D*).

It is noteworthy that an incompletely formed circle of Willis was never observed in the series reported above, or in the thousands of circles studied more recently. Invariably, whenever an apparent break in the circle was observed, careful dissection revealed the break being bridged by a brush of smaller blood vessels.

These are not interesting observations of no clinical importance. Instead, they are extremely vital and of everyday interest to clinicians dealing with the brain. Faced with cerebral aneurysms or vacular malformations, it is a great comfort to know that the affected half of the brain will continue to receive an adequate amount of blood from the contralateral side when its internal carotid artery is tied off. Although the circle of Willis itself is usually not visualized, significant information concerning its adequacy as a shunt can be obtained by injecting an internal carotid artery while applying contralateral pressure during the injection. By so doing, and by being fully aware of the variants that commonly abide in the circle, great clinical harm will be avoided.

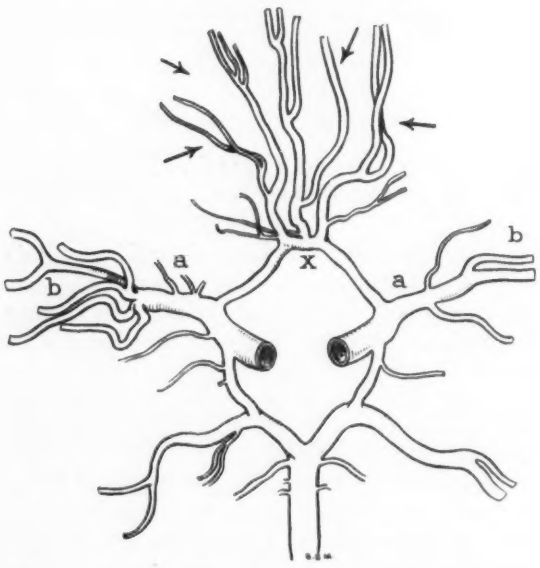


FIG. 3. Circle of Willis revealing multiple anterior cerebral arteries arising "*x*." The main branches of the middle cerebral arteries are seen at "*a*." Note the asymmetrical character of the branches of the middle cerebral arteries on each side, "*b*."

Of considerable interest also was the common occurrence of congenital anomalies in the ascending portion of the anterior cerebral artery (Fig. 3). Whereas usually this coursed as a single artery above the optic chiasm, there were many instances of reduplication of this artery. Viewed in lateral roentgenograms, these reduplicated vessels often suggested that both anterior cerebral arteries were being flooded with contrast medium when actually but one vessel plus its anomalous tributaries were being seen. In rare instances small arteries were seen springing from the anterior communicating artery itself causing still further confusion in single lateral roentgenograms. Obviously, informative sagittal examinations almost always resolved these uncertainties.

In our postmortem experience we never saw an anterior cerebral artery displaced appreciably laterally in the absence of a space-taking lesion. Gentle undulations across the midline were observed but in each instance the anterior cerebral artery seemed to course equally to either side of the midline (Fig. 4). On several occasions the undulation failed to cross the midline but its configuration caused us no concern (Fig. 5). The observation was impressive because of its potential clinical significance.

One technical observation merits emphasis. By rotating the head from its true anteroposterior plane, one occasionally produced an apparent lateral deviating of the anterior cerebral artery in a healthy brain. (Fig. 6). This was an artefact caused by the anterior, and then posterior sweep of the anterior cerebral artery as it coursed around the genu of the corpus callosum. The latter, lying in the anterior portion of the head, and at a distance from the film itself in anteroposterior roentgenograms, was easily distorted by even minor degrees of rotation.

The middle cerebral artery also proved to be extremely interesting. Whereas its major branches were rather constant, the manner in which the artery itself arose and divided from the internal carotid artery was not.

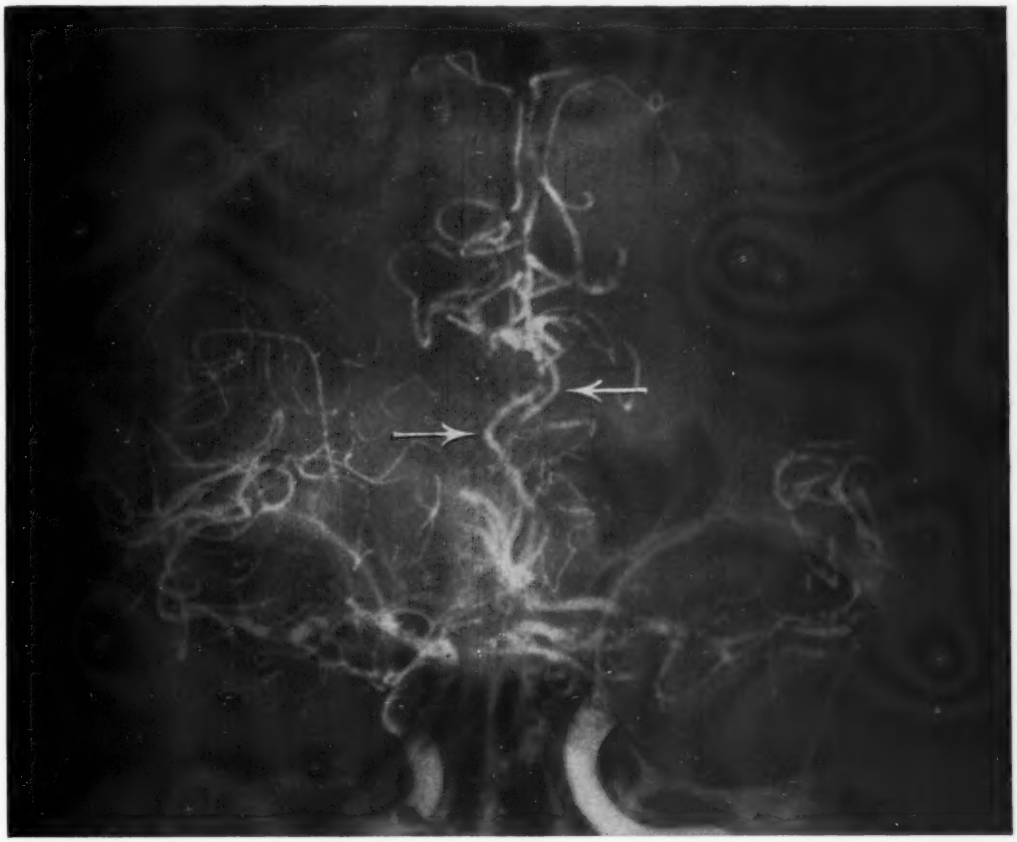


Fig. 4. Autopsy specimen. Note the symmetrical undulations of the anterior cerebral arteries as they cross the midline equally to either side.

According to some anatomic textbooks, the middle cerebral artery arises as a single branch from the internal carotid bifurcation. Common though this configuration was in our postmortem material, on many occasions two, and even three, such middle cerebral vessels were found leaving the internal carotid artery. Even more complex was the manner in which the middle cerebral artery divided to supply the convexities of the frontal, parietal, temporal, and occipital lobes (Fig. 7). Roentgenographically, the summation of these middle cerebral vascular patterns grossly resembled each other as one proceeded to view them from case to case. When one tried to superimpose individual vessels from different specimens, or both sides of the same specimen, analysis of the middle cerebral group became utter confusion. Thus it was that we grasped the true significance of Egas Moniz' term "groupe sylvienne" as he applied it to these vessels.[3,4] He chose to consider these arteries as a group rather than individual anatomic structures.

Of considerable interest was the manner in which the sylvian group of vessels hugged the inner surface of the cranial vault when viewed in the anteroposterior roentgenogram. Adequately filled, the smaller vessels of the cranial convexity gave the appearance of emptying directly into the bones of the calvaria, so intimately placed were they against the inner table of the skull (Fig. 8). It is this normal relationship that makes it possible for one to recognize epidural and subdural bleeding by cerebral angiography. In the latter, a clear space is seen which represents fluid collected between the vessels of the convexity

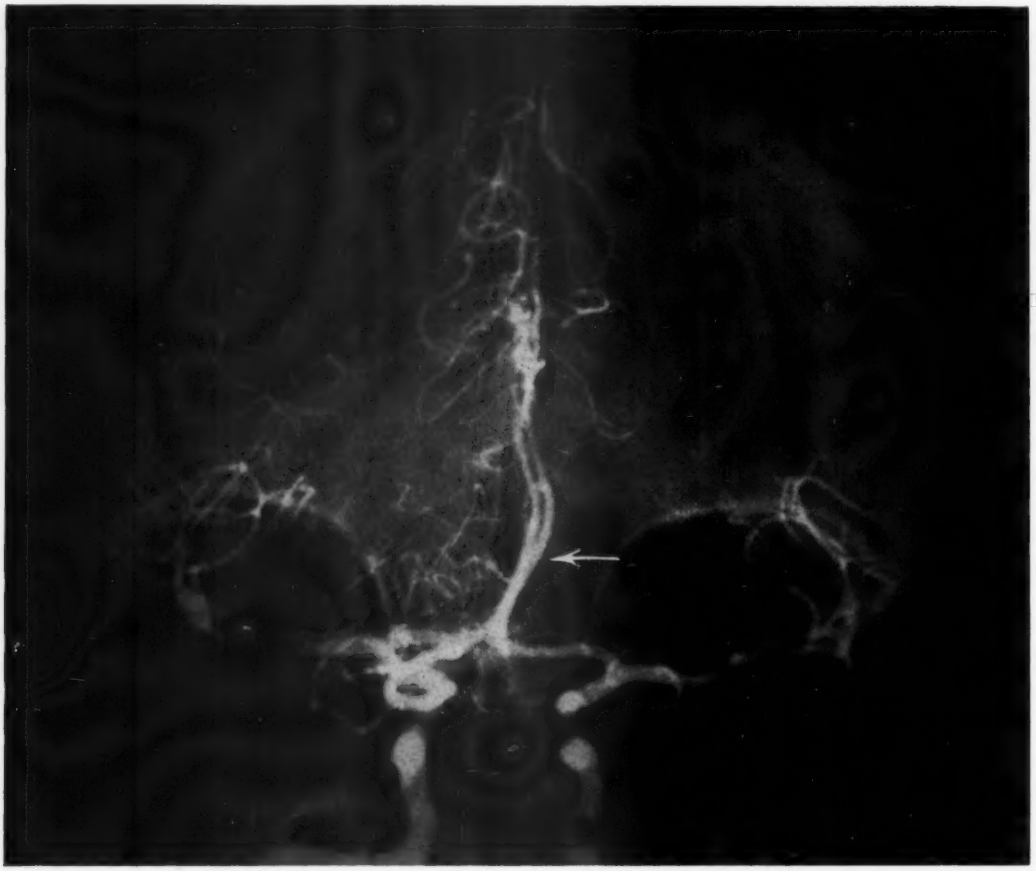


FIG. 5. Autopsy specimen. An anatomical variant of the anterior cerebral arteries which crossed the midline to one side only. On examination the brain was normal.

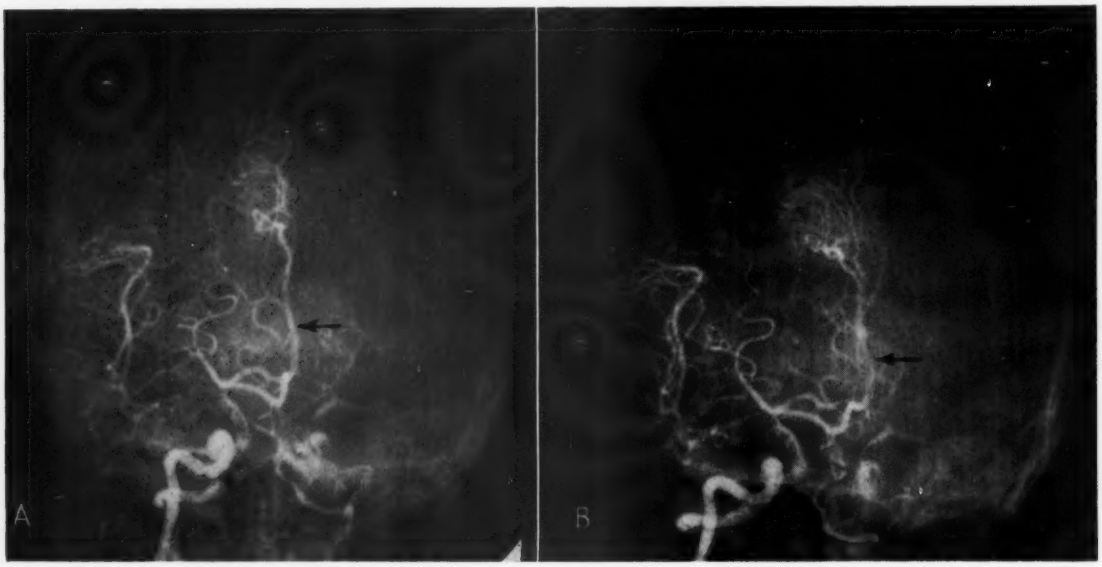


FIG. 6. Autopsy specimen. In the true anteroposterior projection (*A*) the anterior cerebral artery is in the midline. Slight rotation of the head (*B*) reveals apparent displacement of the anterior cerebral arteries.

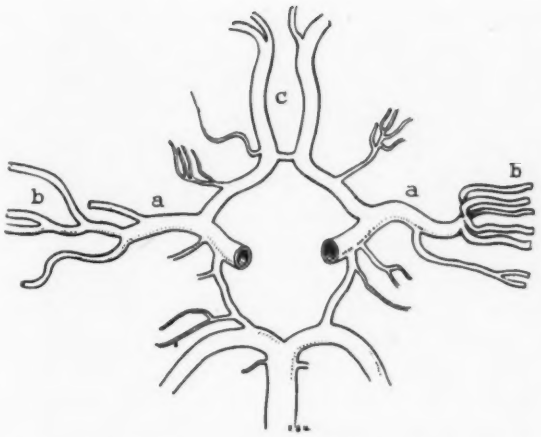


Fig. 7. Circle of Willis revealing marked differences in the appearance of each middle cerebral group of vessels. The middle cerebral arteries are seen at "*a*," their branches at "*b*." The anterior cerebral arteries are at "*c*."

of the brain and the inner table of skull.[20]

As a rule, viewed in the anteroposterior projection, both middle cerebral arteries mirrored each other. Usually their lateral course from the bifurcation of the internal carotid artery to the sylvian fissures looked the same on both sides. Occasionally, they varied suggesting the presence of a deep-seated temporal lobe lesions. The difference was not striking (Fig. 8). To anyone seeking a lesion in this area, however, it could cause concern.

The importance of properly positioning the head for lateral cerebral angiograms was also amply demonstrated by post-mortem studies. Here, as in the sagittal plane, the blood vessels could be made to appear distorted by tilting the head (Fig. 9). By so doing, one projected the middle cerebral group above its normal plane, suggesting the presence of a temporal lobe lesion.

A great deal was learned by bisecting cerebral hemispheres in the sagittal plane and studying separately the anterior and middle cerebral arteries (Fig. 10 and 11). The anterior cerebral artery, supplying the middle half of the brain, and the middle cerebral artery supplying the lateral convexities of the brain, it was possible, by slicing between these regions, to obtain roentgenograms of the middle half of the cerebrum with its vascular supply in one exposure and the convexities of the brain in a second. Study of the separate vascular patterns obtained by this technique helped considerably to clarify and crystallize fun-

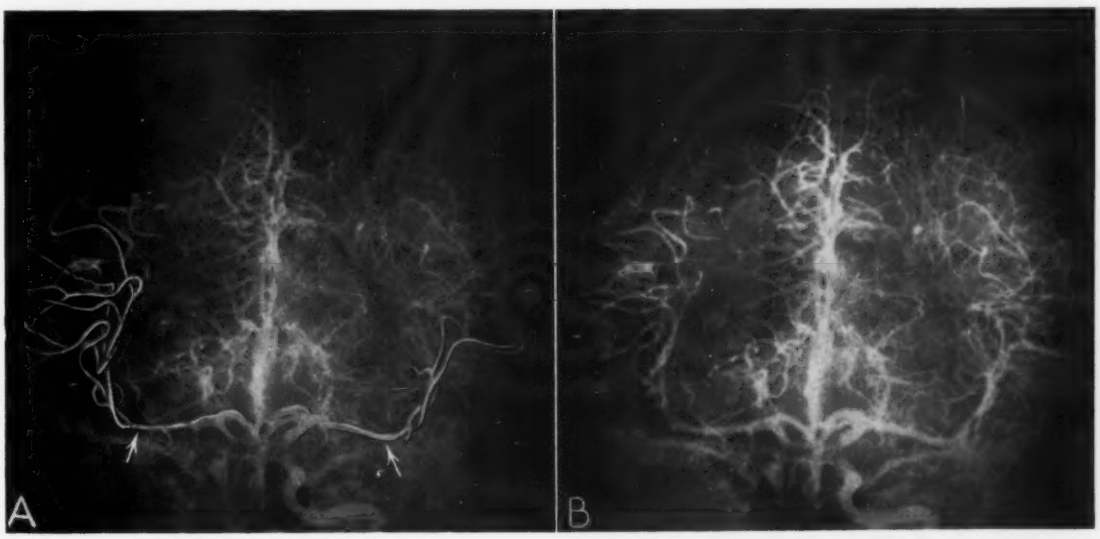


Fig. 8. Autopsy specimen. The small blood vessels covering the convexities of the brain hug the inner table of the bones of the calvaria into which they appear to empty. Note the asymmetry of the middle cerebral arteries indicated by the arrows. (*A*) and (*B*) are identical reproductions except for the retouched vessels in (*A*).

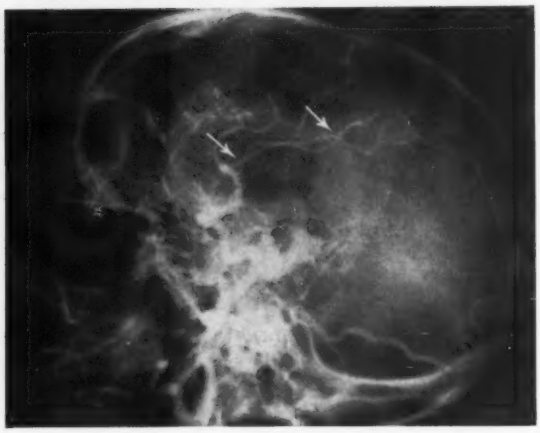


FIG. 9. The apparent upward displacement of the middle cerebral group of vessels is due to faulty position of the head.

damental vascular anatomy. It re-emphasized the anterior and medial position of the anterior cerebral artery and its tributaries. The sections also enhanced one's appreciation of the lateral and somewhat posterior distribution of the middle cerebral group. Slices were also made transversely and vascular patterns studied in these projections (Fig. 12 and 13). By so doing it was possible to study brain sections in both planes. The net result was a more intimate understanding of fundamentals and a better appreciation of where expanding lesions must arise in order to produce various types of vascular displacement.

According to some individuals, the rolandic and sylvian fissures bear a constant relationship to the bony landmarks of the skull. Diagrams illustrating this relationship may be found in various texts tending to support this concept. Some have based their measurements upon the contour of the cranial vault determining specifically its length from the base of the nose to the base of the skull.[16,19] Others have employed various base lines running through the upper and lower margins of the orbit and the external auditory canal which have then been variously divided perpendicularly.[16] The most recent attempt at standardizing the position of the sylvian fissure employs two lines, one of which is drawn from the internal occipital protuberance to the center of the sella turcica, and a second line drawn through the course of the middle cerebral group of arteries.[22] It is claimed that the angle between these lines almost always falls between 36 and 44 degrees.

Were the above measuring and angulat-

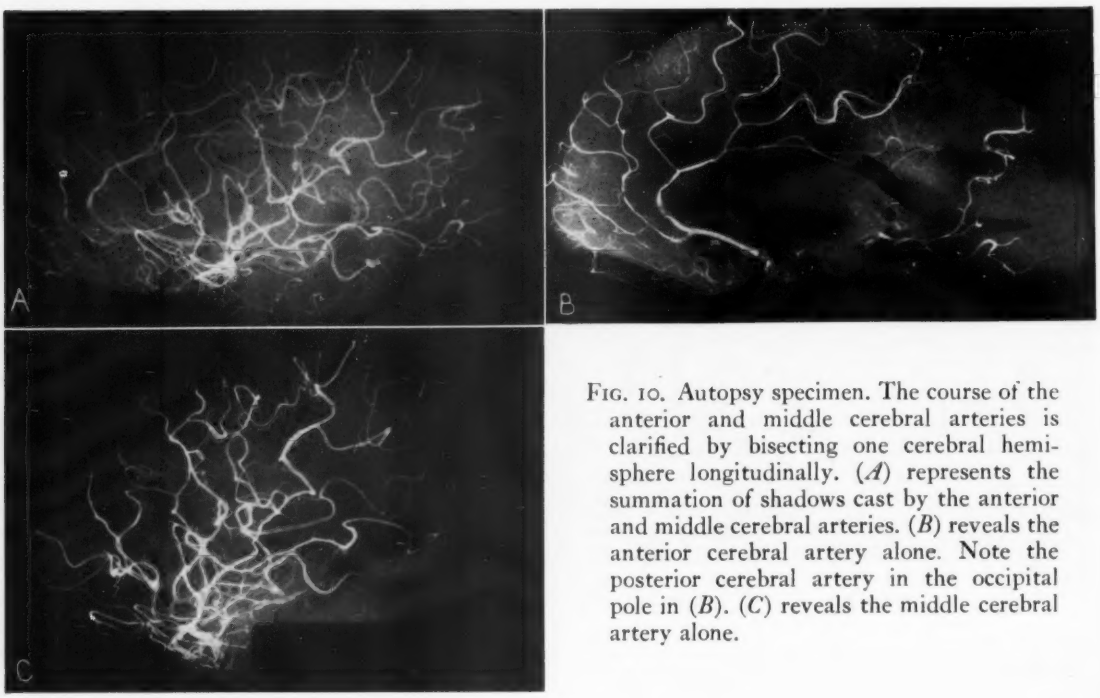


FIG. 10. Autopsy specimen. The course of the anterior and middle cerebral arteries is clarified by bisecting one cerebral hemisphere longitudinally. (*A*) represents the summation of shadows cast by the anterior and middle cerebral arteries. (*B*) reveals the anterior cerebral artery alone. Note the posterior cerebral artery in the occipital pole in (*B*). (*C*) reveals the middle cerebral artery alone.

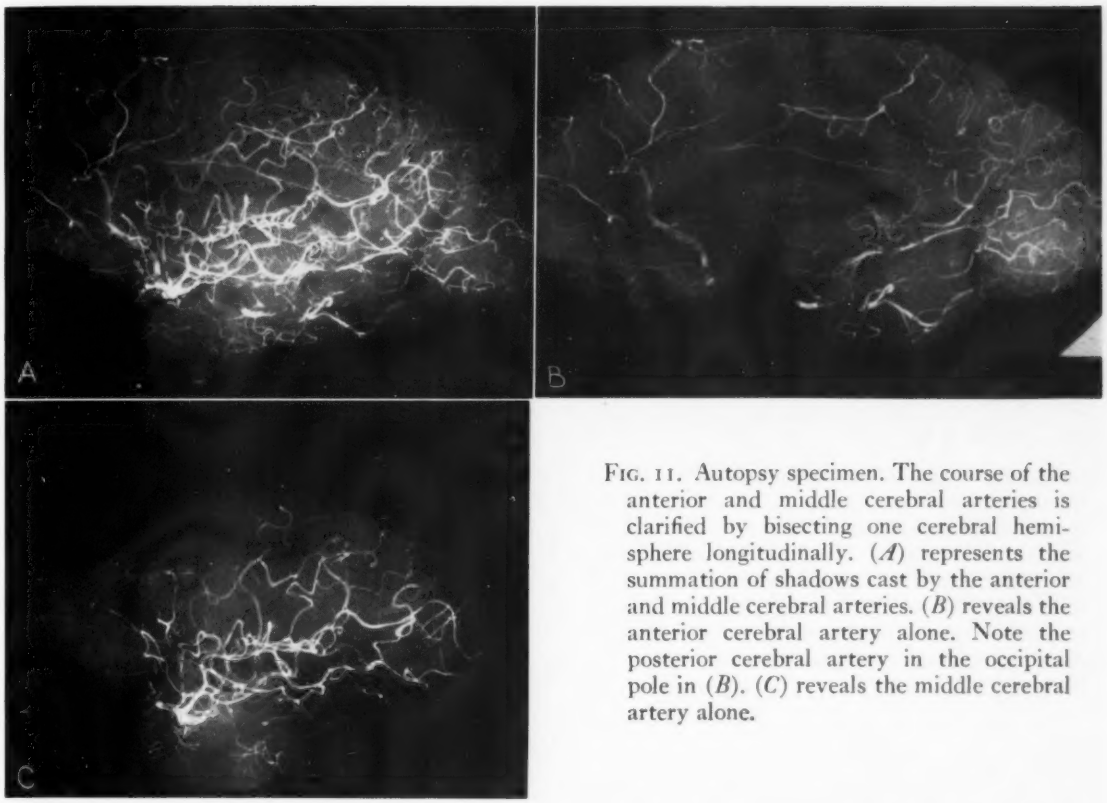


Fig. 11. Autopsy specimen. The course of the anterior and middle cerebral arteries is clarified by bisecting one cerebral hemisphere longitudinally. (*A*) represents the summation of shadows cast by the anterior and middle cerebral arteries. (*B*) reveals the anterior cerebral artery alone. Note the posterior cerebral artery in the occipital pole in (*B*). (*C*) reveals the middle cerebral artery alone.

ing devices reliable for estimating the position of normal cerebral landmarks, they would be of inestimable value in helping one determine minor alterations in the course of the arteries of the brain, particularly the sylvian group. In our experience these methods have not stood the test of cerebral angiography either in the living or in our postmortem material.

Whereas the vessels in the posterior fossa of the skull were often visualized when excessive quantities of radiopaque solution were injected into an internal carotid artery in a cadaver, we chose also to study these vessels by selective injections of vertebral arteries after ligating both posterior communicating branches of the circle of Willis. By so doing, complicating cerebral vascular components were avoided, permitting better visualization of the basilar artery and its branches.

The paired arrangement of the vessels springing from the basilar artery, plus their tendency to overlap, and their small lumen, made their recognition in the lateral plane difficult. Usually, the basilar, posterior cerebral, and superior cerebellar arteries were identified with ease in spite of the overlapping temporal bone. The remaining branches of the basilar artery were less adequately visualized.

In our postmortem material, after roentgenographing the vessels supplied by the vertebral arteries within the skull, the entire brain, including the cerebellum, was again roentgenographed outside of the head and corresponding dissections completed.

Most striking, though not unexpected, was the complete inconstancy of the course of the basilar artery. Not only did it vary in length, bifurcating at various levels with respect to the dorsum sellae, but it also varied with respect to its own parallel relationship to the plane of the clivus and dorsum (Fig. 14). In some, it hugged the clivus, drifting but slightly away from the dorsum. In others, a considerable space

separated the vascular and bony structures. Even more startling was its relationship to the clivus as viewed in the sagittal projection. Rarely did it occupy a midline position. More commonly, particularly in sclerotic individuals, it drifted to one side or the other forming an irregular "C" or "S" (Fig. 15). It soon became obvious that one could not lateralize posterior fossa lesions by observing minor lateral shifts of the basilar artery alone.

Equally interesting were the posterior cerebral arteries. Whereas some symmetry was observed as they coursed dorsally from the basilar artery over the petrous bone to divide into their terminal branches

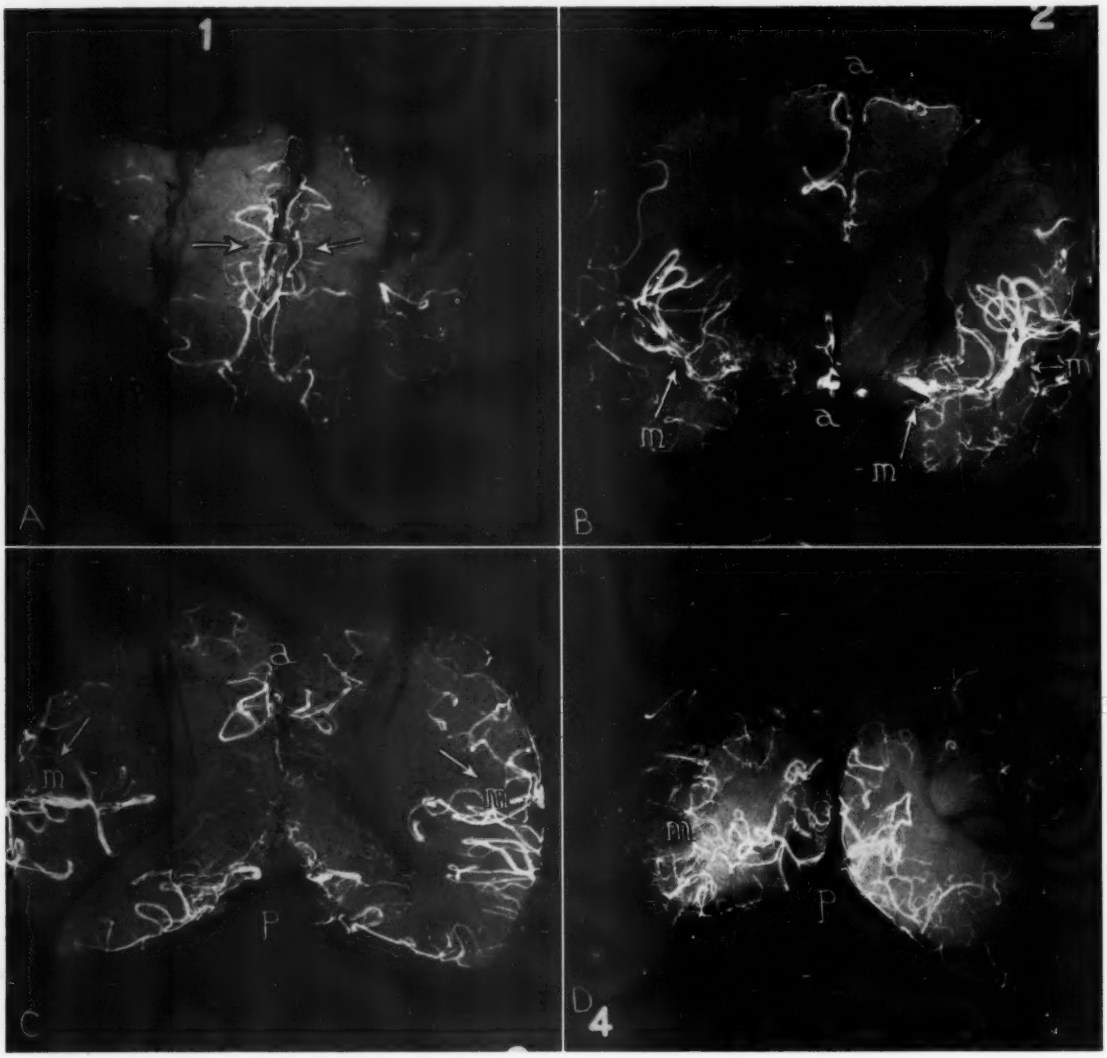


FIG. 12. Autopsy specimen. Transverse sections of the brain revealing relative position and course of the anterior, middle and posterior cerebral arteries. The artifact between the major vessels represents the longitudinal cuts seen in Figures 10 and 11. (*A*) reveals the anterior portion of the frontal lobes with its anterior cerebral arteries. (*B*) is a section through the site of origin of the main branches of the middle cerebral arteries, "*m.*" Notice the course of the middle cerebral vessels, "*m,*" around each island of Reil. The anterior cerebral arteries are seen at "*a.*" (*C*) is a transverse section through the anterior portion of the parietal lobes. Note the more superficial distribution of the middle cerebral vessels, "*m.*" The posterior branches of the anterior cerebral artery are seen at "*a.*" Branches of the posterior cerebral arteries lie at "*p.*" (*D*) represents the occipital poles supplied mainly by the posterior cerebral arteries "*p*" and terminal branches of the middle cerebral arteries "*m.*"

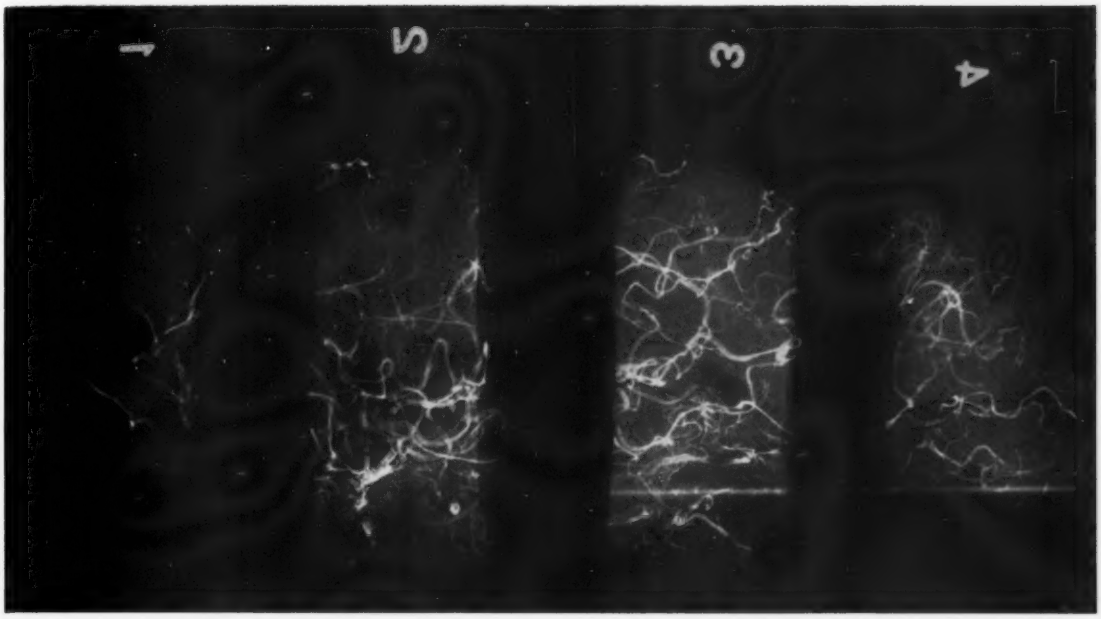


Fig. 13. Autopsy specimen. Lateral view of cut sections of the brain viewed in the anteroposterior projection in Figure 12. Sections *1*, *2*, *3*, *4* are (*A*), (*B*), (*C*), (*D*) respectively in Figure 12.

in the lateral view, a complete absence of symmetry was often the case in the anteroposterior projection (Fig. 16). Ordinarily, it would seem reasonable to expect that these arteries, arching as they do around the cerebral peduncles, might be curved symmetrically. That this was not the case was amply demonstrated by our postmortem correlation studies (Fig. 17). Of all the vascular landmarks in the brain, these arteries in the posterior fossa can be and often are the least informative as well as the most confusing. This is particularly true when minor anatomical variants coincide with the side of the patient's suspected lesion. Major distortions can be recognized at a glance; the minor ones pose the problems.

The superior, middle and inferior cerebellar arteries also were asymmetrically paired, the superior group being the most easily recognized. Coursing as the latter do around the mid-brain, the superior cerebellar arteries were best seen in the anteroposterior projection where they often were superimposed upon the larger paired posterior cerebral arteries (Fig. 18).

Many of our cadavers were over sixty years of age, some eighty and ninety. A great many arteriosclerotic brains were therefore examined. The carotid siphon revealed remarkable variations in these individuals. Some were acutely kinked, others elongated. Many revealed the filling defects of atheromatous plaques. The smaller vessels revealed changes far less commonly. Occasionally they seemed tortuous and, in rare instances, pathologic variations were seen in their size and profile (Fig. 19).

As our studies progressed the desirability of obtaining cerebral angiograms routinely in postmortem material became increasingly obvious. This seemed particularly important when the brain was not included in the autopsy. Several times we demonstrated thrombosis of the internal carotid artery when it was not recognized clinically. One of our earliest injections revealed bilateral carotid thrombosis, unrecognized (Fig. 20). Once we demonstrated a vascular leak in the optic thalamus (Fig. 21). A peculiar retro-orbital collection of arteries were found behind the eye in another individual (Fig. 22).

Extremely interesting were the small

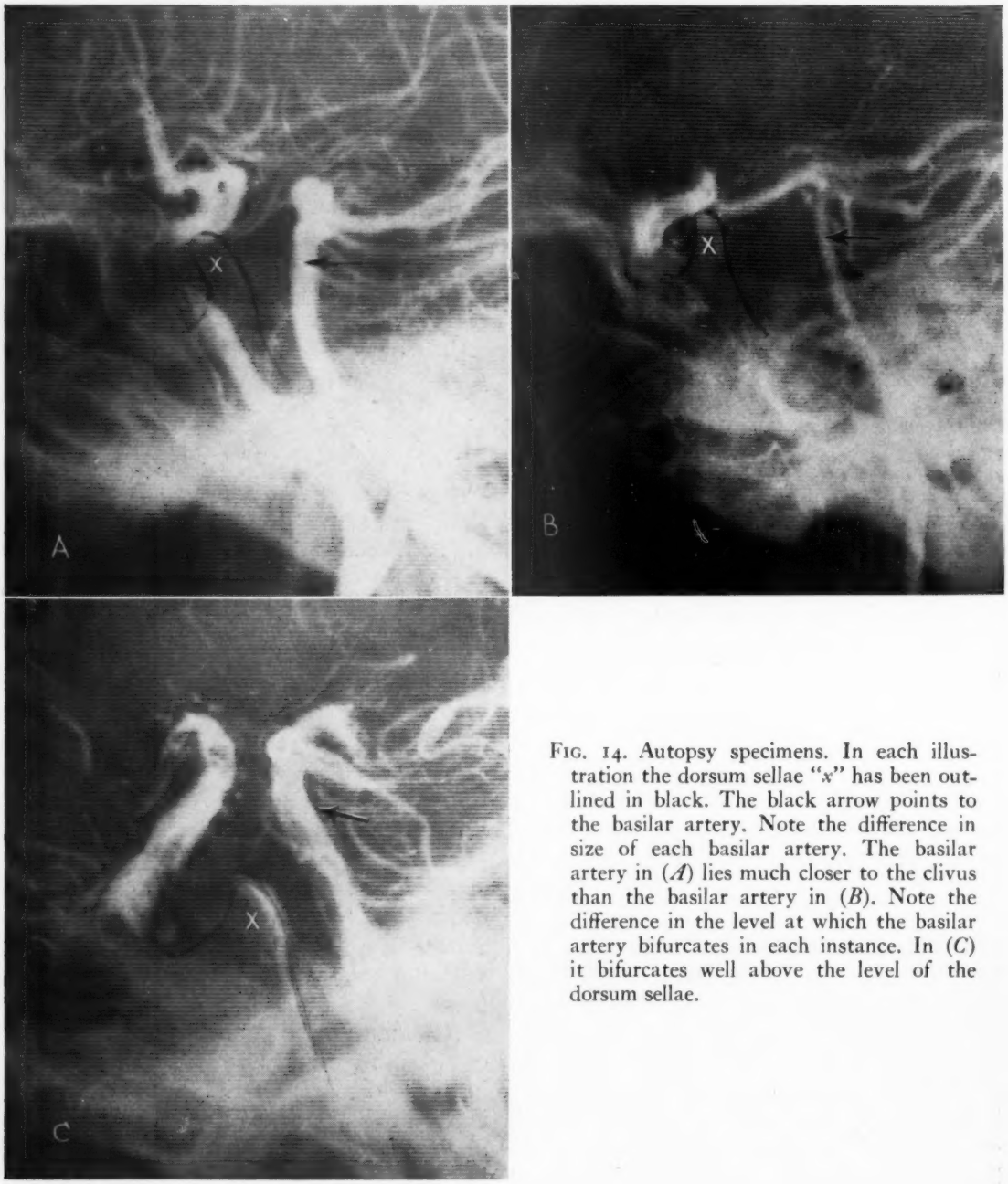


Fig. 14. Autopsy specimens. In each illustration the dorsum sellae "*x*" has been outlined in black. The black arrow points to the basilar artery. Note the difference in size of each basilar artery. The basilar artery in (*A*) lies much closer to the clivus than the basilar artery in (*B*). Note the difference in the level at which the basilar artery bifurcates in each instance. In (*C*) it bifurcates well above the level of the dorsum sellae.

arteries seen in roentgenograms of the brain that were never identified in films of the intact head. These were innumerable and delicate, obviously too small to be picked up in routine angiograms because of overlying bone (Fig. 23). More easily identified was the choroid plexus, also often seen in the living. In rare instances the lenticulostriate arteries were beautifully visualized (Fig. 24). Time and again were we impressed by differences in size of the vessels in the outer layers of the cerebral cortex compared with those penetrating the white matter. Rarely did we see a sizable artery piercing the deeper layers of the brain. It brought to mind Wislocki's

concept of the relative order of magnitude of the arteries of the brain.[21] He divided them into 7 categories, according to size, three or four of which may be of roentgen significance, the rest being too small to see (Fig. 25). The largest, the carotid and vertebral arteries, were of the seventh order of magnitude and estimated to be 2 to 3 mm. in diameter. The middle cerebral, measuring 1.5 to 2 mm. in diameter, he classified as sixth. The smaller, freely anastomosing vessels covering the brain and its outer layers were classified fifth in size. Fourth in magnitude were vessels like the lenticulostriate artery that pierce the brain measuring 16 to 51 micra, still visible roentgenographically. Vessels in the remaining categories were progressively smaller and of no practical roentgen importance.

FIG. 15. Autopsy specimen. Note the unusual tortuosity of the basilar artery as indicated by the arrows. The divisional branches of the basilar artery are seen at "*a*."

PHYSIOLOGICAL CONSIDERATIONS

Until recently, only experiments in lower animals contributed our information concerning cerebral circulation. By examining retinal vessels in animals, the oxygen content of their internal jugular and arterial blood, and by contrast medium techniques, some insight into the problems of human circulation was acquired. Cadavers alone supplied what we knew about the cerebral circulation in man. In most instances, conjecture led to accepted opinions regarding the flow of blood and its ultimate destination in the brain.

At autopsy, when the internal carotid

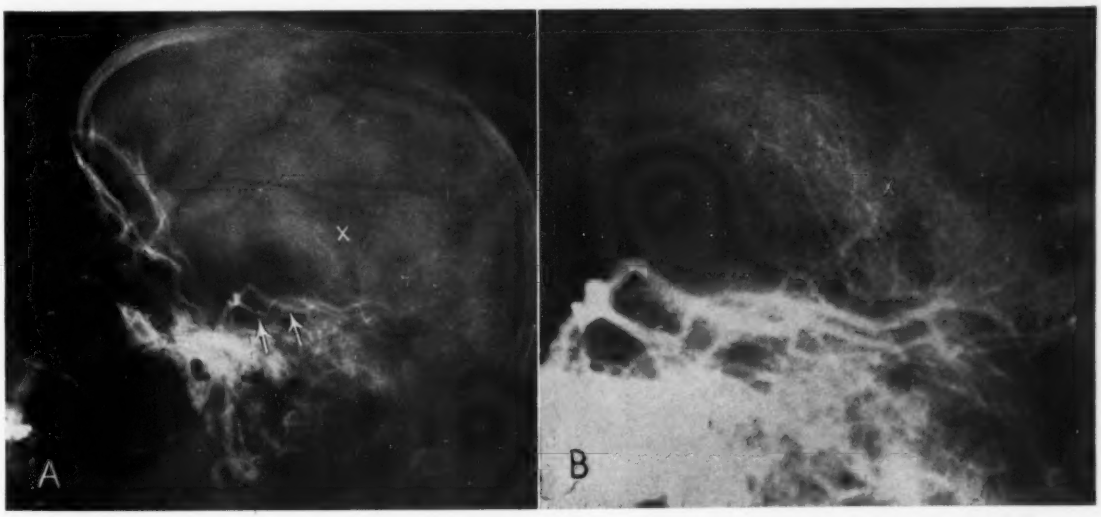


FIG. 16. Injection of vertebral artery in a living subject revealing the course of the posterior cerebral arteries (*A*). (*B*) reveals the posterior vessels magnified. The posterior choroidal arteries are seen at "*x*."

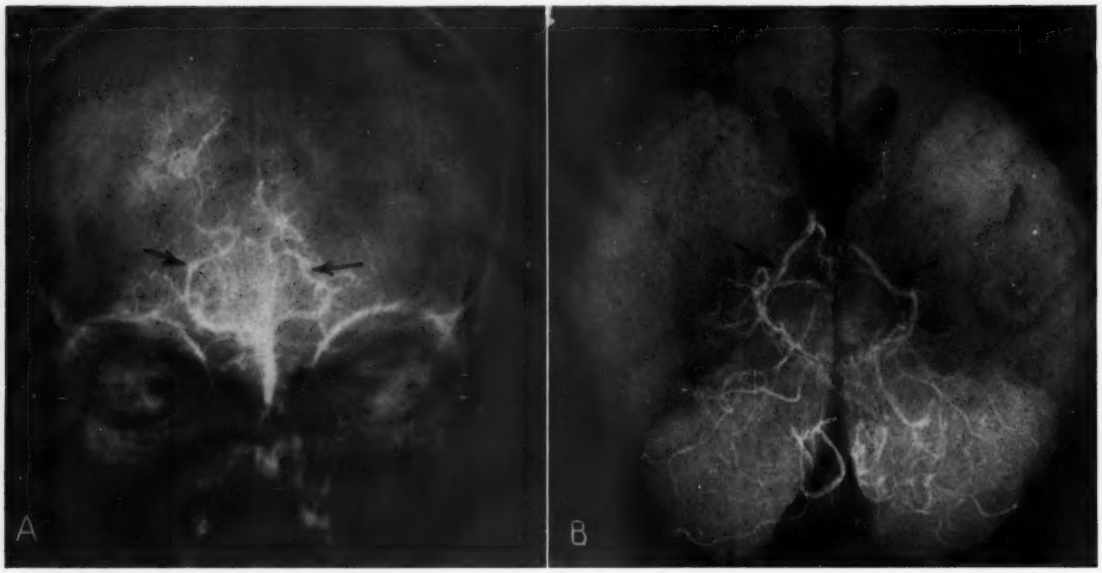


FIG. 17. Autopsy specimen. The black arrows in (*A*) indicate the posterior cerebral arteries as they course around the cerebral peduncles. Their asymmetry is seen to better advantage in (*B*) which is a roentgenogram made of the brain after its removal from the vault.

artery is injected, it takes but a small quantity of contrast solution to flood both hemispheres of the brain. Five to seven cubic centimeters usually suffice to visualize adequately the internal carotid artery and its main branches on both sides. Sometimes the vessels in the posterior fossa may be seen, particularly when a little more

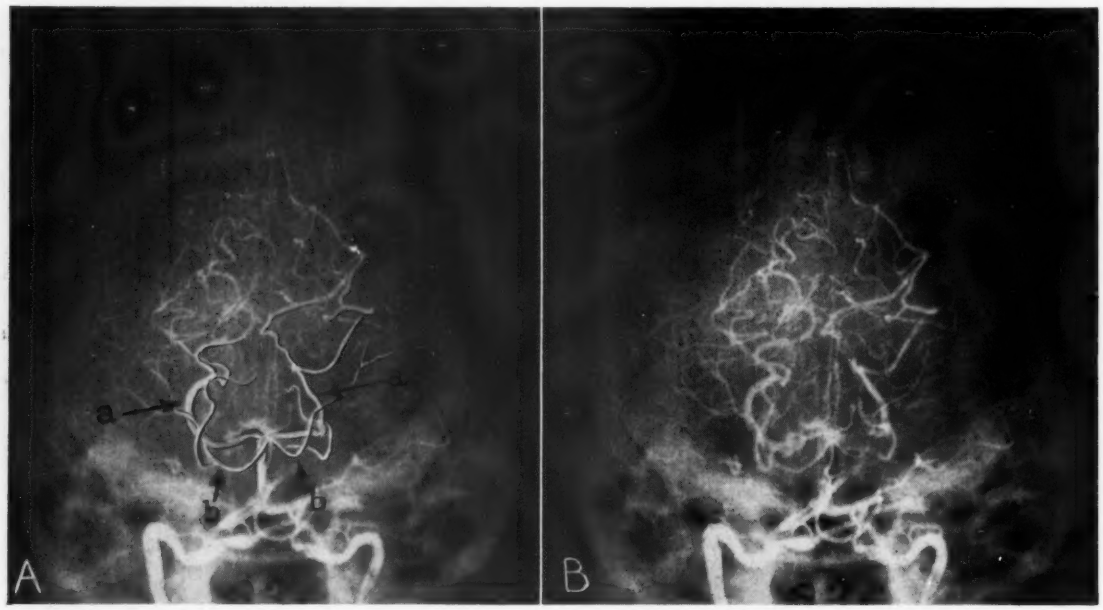


FIG. 18. Autopsy specimen. The injection was made through one vertebral artery after the posterior communicating arteries of the circle of Willis had been ligated. (*A*) and (*B*) are identical illustrations, the main arteries having been brought out to better advantage by the artist in (*A*). The asymmetrical paired cerebral arteries are seen at "*a*." The superior cerebellar arteries, also paired, are seen at "*b*."

Fig. 19. Autopsy specimens. Markedly sclerotic internal carotid arteries are noted in (*A*) and (*B*). Note the point of narrowing in the course of the vessels due to atheromatous plaques identified by the arrows. In (*B*) note the dilated posterior cerebral artery at "*x*."

solution is used and the injection is made more forcefully.

This rarely occurs spontaneously in the living. Usually the homolateral anterior and middle cerebral arteries alone are visualized when an internal carotid artery is injected. Occasionally the contralateral anterior and middle cerebral vessels may be visualized, but as a rule this is done by design or is the result of disease. The reason for this difference is apparent.

The circle of Willis may be considered a constant, albeit irregular, anastomosis between the carotid and vertebral arterial systems. In the living it does not permit a mingling of the blood streams in the main vessels across which it lies because of inherent hydrodynamic characteristics. It

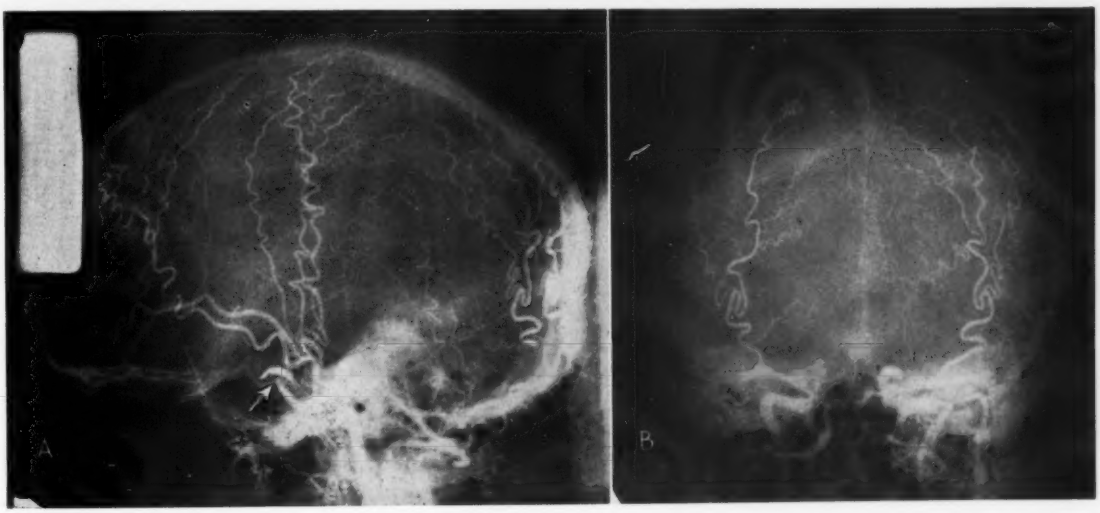


Fig. 20. Autopsy specimen. Bilateral thrombosis of the internal carotid arteries discovered accidentally at postmortem examination. Note the point of occlusion of the internal carotid arteries at the arrow in (*A*). The vessels seen in (*A*) and (*B*) are all tributaries of the external carotid.

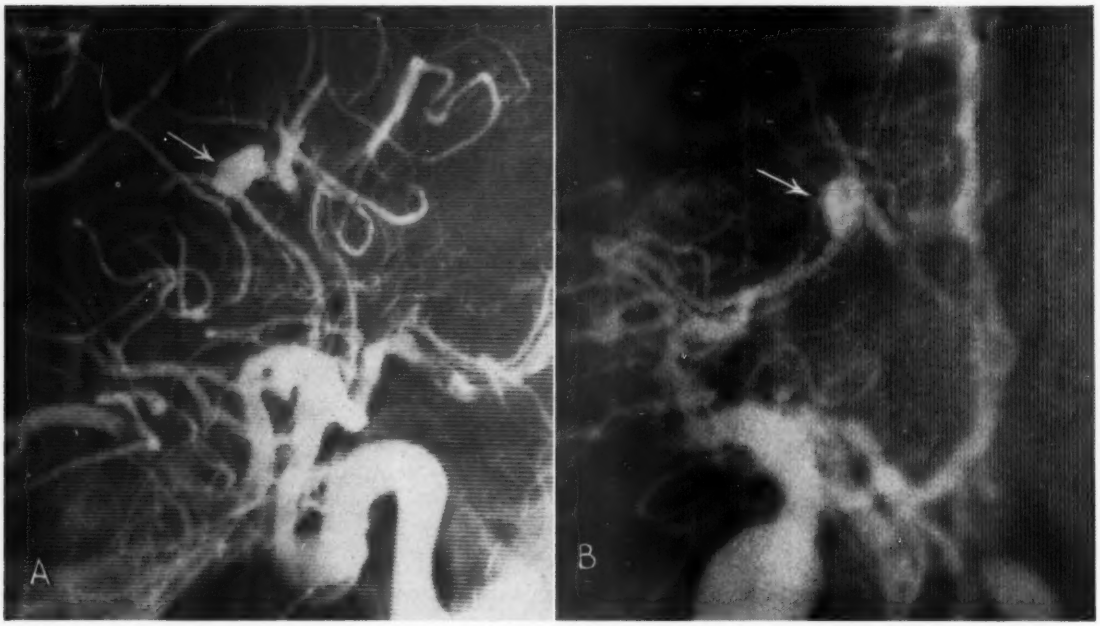


FIG. 21. Autopsy specimen. Perivascular hemorrhage into the optic thalamus. (*A*) lateral view; (*B*) anteroposterior view.

is not a distributor or equalizing station for normal cerebral blood supply. Rather, its value is potential because it provides a bypass which can be utilized when specific segments of the brain are being used requiring additional blood, as well in the presence of vascular obstructions. The importance of this shunt was recently reemphasized when it was demonstrated by cerebral angiography that in cats shunting

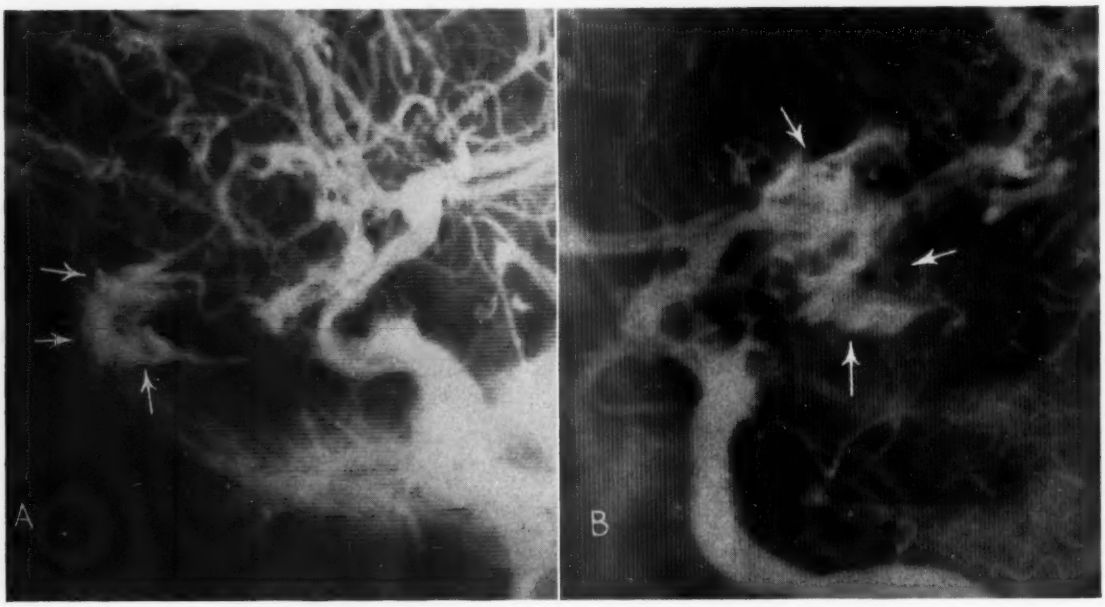


FIG. 22. Autopsy specimen. Anomalous retrobulbar nest of arteries observed lying behind the orbit. No abnormalities had been noted of this individual's eye clinically. The arrows in (*A*) and (*B*) reveal the abnormal cluster of vessels. (*A*) is the lateral projection; (*B*) is the anteroposterior projection.

of arterial blood through the circle of Willis was influenced by the cervical sympathetic trunks.[2] Hydrodynamic forces being nonexistent in cadavers, opacifying media flow equally in all directions, flooding the entire circle of Willis and its branches. In the living, however, pre-established currents determine the course of the opaque solution, making it possible to visualize selective vessels in the brain by injecting known sources of their blood supply.

This partition and distribution of cerebral blood flow was carefully studied recently by means of a contrast medium injection technique in living human subjects.[18] These spectrophotometric investigations indicated that blood entering the brain through an internal carotid artery was almost wholly distributed to the homolateral hemisphere of the brain and was drained predominantly by the internal jugular vein on the same side. It was found also that the blood in each internal jugular vein was fairly representative of the drainage from all of the histologic components of the brain. Noteworthy also was the observation that blood in the internal jugular vein at the level of the superior bulb was relatively free of blood derived from extracerebral sources, while the external jugular vein contained significant quantities of cerebral venous blood.

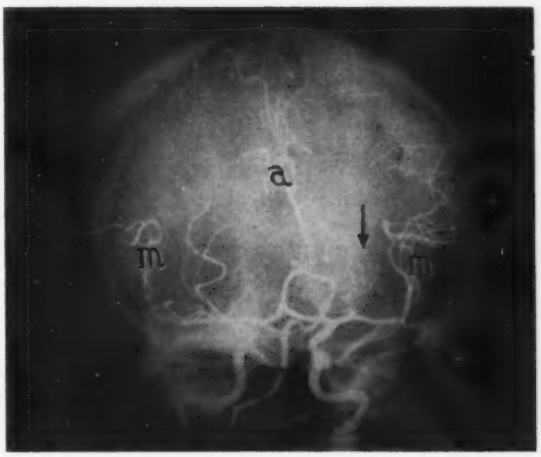


Fig. 24. Autopsy specimen. The lenticulostriate arteries are clearly visualized at the tip of the arrow. The middle cerebral arteries are indicated by "*m*" and the anterior cerebral arteries by "*a*." Note: this head is slightly rotated.

Commonly accepted by physiologists was the fact that if one could measure the

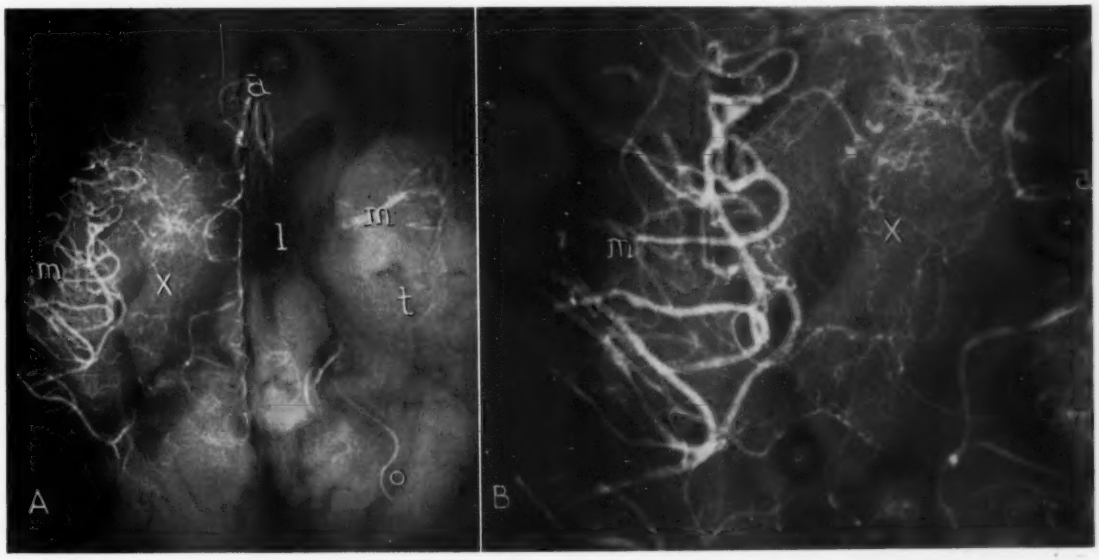


Fig. 23. Autopsy specimen. Coronomental exposure of the brain after it had been removed from the vault and hardened. Air can be seen in the ventricular system. Lateral ventricle is seen at "*l*," the occipital horn at "*o*," and the temporal horn at "*t*." The course of the main branches of the middle cerebral artery are seen at "*m*." The anterior cerebral arteries are seen at "*a*." Note the small vessels in the mid-portion of the brain at "*x*." (*B*) a magnification of area "*x*" to show the small vessels to better advantage.

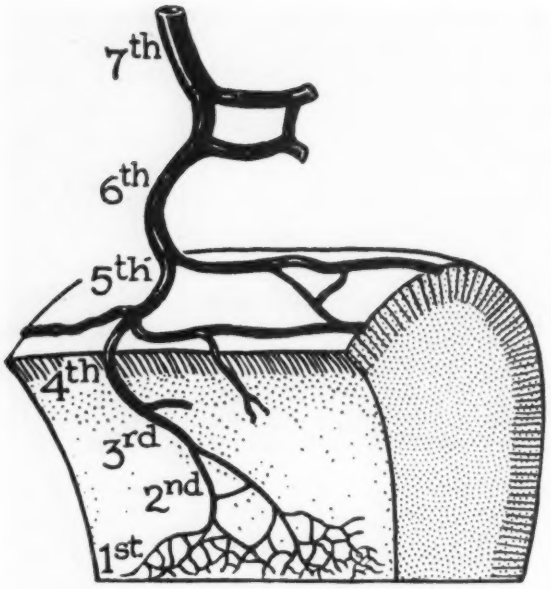


FIG. 25. The relative order of magnitude of the arteries of the brain are depicted in this diagram which was adapted from Wislocki.

quantity of a substance removed from the blood by an organ and, during the same time, the difference in concentration of that same substance in the blood as it entered and left the organ, one could calculate the rate of blood flow through said organ by applying the Fick principle. Using this physiological principle, Kety developed a nitrous oxide method for determining cerebral blood flow that has opened the entire field of cerebral physiology for quantitative investigation at a clinical level. The information recorded below, concerning cerebral physiology, has been taken freely from the works of Kety, Schmidt, and their co-workers.[8,9,10,15] A complete review of the papers published by this group lies beyond the province of this communication which will but summarize briefly the more significant observations. Those interested in cerebral physiology will find a wealth of significant and important material in the original articles.

It is now known that the rate of blood flow through the brain approximates 54 cubic centimeters per 100 grams of brain per minute, or 740 cc. per minute for an entire brain of average weight. Also known now is the oxygen consumption of the normal brain, which has been established at 3.3 cc. of oxygen per 100 grams of brain per minute, or 46 cc. per minute for the entire organ. Considering that the brain represents but 2 per cent of body weight, it is most remarkable, as Kety has pointed out, that it normally receives about one-sixth of the heart's output of blood and consumes nearly 20 per cent of all the oxygen utilized by the body.[10]

Herein lies the explanation for the prompt appearance of contrast medium in the branches of the internal carotid artery when the common carotid is injected. There is far greater flooding of the brain than the tissues supplied by the external carotid. Thus it is that the middle and anterior cerebral arteries usually are visualized seconds ahead of the vessels of the cranium and scalp when the common carotid artery is injected.

The rate of the cerebral blood flow appears to depend upon two factors, each of which may be influenced by many variables. The first factor is the *pressure head*, or difference between the arterial and venous pressures at the level of the cranium. Determined largely by the mean arterial blood pressure, it is zealously guarded by numerous homeostatic mechanisms such as the carotid sinus reflex and cerebral control of peripheral vascular tone. Recent data have not substantiated the commonly accepted concept that cerebral blood flow follows passively changes in arterial pressure. As long as the mean arterial pressure remains above a critical minimal level, cerebral blood flow appears to be regulated intrinsically by changes in cerebral vascular resistance.

The second and far more important factor controlling cerebral blood flow is the *resistance* or hindrance imposed upon the flow of blood by the vessels of the brain. It represents the net effect of many factors tending to impede the flow of blood through the brain, including changes in intracranial pressure, blood viscosity, as well as the changes in the cerebral vessels themselves, whether they be functional or organic.

Intracranial Pressure. The increased

blood pressure that often accompanies increased intracranial pressure probably represents nature's effort to maintain cerebral blood flow. With excessive increases in cerebrospinal fluid pressure, however, the compensatory mechanism breaks down and significant cerebral circulatory insufficiency may result. This has been attributed to the fact that the thin walled vessels of the brain accurately reflect changes in pressure in the cerebrospinal fluid within which they are immersed.

The cerebrospinal fluid also serves an important function in maintaining cerebral blood flow. The only important distensibility of the cranial cavity and its contents lying in its veins, which are in direct communication with the great veins of the body, the cerebrospinal fluid, from the point of view of hydraulics, becomes a part of the venous system of the body reflecting instantly changes in venous pressure. Thus it is that sudden coughs, sneezes, and strains, causing immediate rises in intracranial arterial and venous pressure, produce at the same time a parallel increase in intracranial pressure. It is because this neutralizing mechanism is so effective that the small vessels of the brain do not burst more often than they do.

Blood Viscosity. Relatively constant in most healthy individuals, blood viscosity largely depends upon the proportion of erythrocytes present. The fact that the more viscous a fluid is, the more frictional resistance it offers, probably explains why it is that cerebral blood flow is accelerated in the presence of severe anemia and retarded in polycythemia vera. That such altered blood flow also serves to maintain a constant cerebral oxygen supply in anemia and polycythemia is the obvious corollary.

Organic Vascular Changes. It was assumed for years that cerebral vascular sclerosis imposed a resistance to cerebral blood flow that could ultimately lead to decreased cerebral function and organic degeneration. Current observations in living human subjects have substantiated this belief.

The tremendously accelerated blood flow observed in patients with cerebral arteriovenous malformations merits comment at this time also. Shunts exceeding 1 liter per minute have been recorded in these cerebral anomalies which are known to have caused measurable increases in cardiac output.[17]

Cerebral Vascular Tone. Alterations in this function maintain a remarkable stability of cerebral blood flow. Achieved by neurogenic reflexes, by humoral agents and by drugs, its mechanisms still are not entirely understood.

Neurogenic control seems to be maintained by sympathetic fibers, that pass through the cervical sympathetic chains and stellate ganglion, and the vasodilator fibers which originate in the medulla and traverse the facial and greater superficial petrosal nerve. Although the existence of the vascular innervation is accepted by most investigators, its exact functions remain vague and equivocal. The fact that clinically stellate ganglion blocks, resections, and stimulation have been followed by significant changes in cerebral blood flow, is worthy of comment.

The *chemical* control of vascular tone is well established and better understood. It has now been established beyond doubt that carbon dioxide decreases cerebral vascular resistance and accelerates cerebral flow. Quantitatively, it has been established that breathing 5 to 7 per cent carbon dioxide increases the cerebral blood flow by about 75 per cent. This information is being used clinically in anesthesiology where one finds 5 to 7 per cent carbon dioxide being used postoperatively to accelerate cerebral blood flow, thereby hastening removal of anesthetics from the brain.

Intimately connected with the carbon dioxide effects upon vascular tone is the part played by altered hydrogen ion concentrations. It may be that the mild acidosis produced by breathing 5 to 7 per cent carbon dioxide may have more effect upon the cerebral vascular tone than the carbon dioxide itself.

Oxygen tension is also an important factor in regulating cerebral vascular resistance. Reliable evidence now indicates that anoxia is just as effective a vasodilator in the brain as are therapeutic concentrations of carbon dioxide.

Extremely important, although little understood, are the *zonal adjustments of cerebral blood flow* that respond to local metabolic needs. Commonly accepted now is the fact that increased localized function of the brain is attended by increased localized circulation in the same area. Experimentally this has been repeatedly demonstrated by shining bright lights into the eyes of animals and observing local increases in occipital cortex circulation. What adjustments take place in cerebral vascular tone to permit such localized flooding, and how they are initiated, remain mysteries.

Whereas in man the effect of drugs upon vascular tone has not proved consistent, experiments in animals have indicated that cerebral vasodilator and constrictor drugs do exist. A large variety have been found capable of dilating cerebral vessels but no drug has yet been proved able to constrict them effectively.

The list of *vasodilators* includes essentially those usually used for this purpose elsewhere (nitrites, choline derivatives, the xanthine group, histamine, alcohol, and the opium alkaloids which include morphine, codeine and papaverine). Generally speaking, the intracranial vessels seem less sensitive to these agents than the extracranial vessels.[10,15]

The strongest cerebral *vasoconstrictor* is decreased CO_2 tension. Only a few drugs appear to have this effect, and in these the effect is not startling. The intracranial vessels seem relatively insensitive to the entire group of sympathomimetic amines (epinephrine, ephedrine) and completely insensitive to posterior pituitary preparations. These drug effects have been studied by cerebral angiography in humans. In a limited number of patients, histamine caused cerebral vasodilatation and ergotamine tartarate, vasoconstriction. It is only fair to say that half of the patients revealed no response at all; those who did respond did not respond uniformly.[5]

We use papaverine routinely in all patients subjected to cerebral angiography. We believe we obtain more uniform filling with it. Not infrequently we also try to block the cervical sympathetics, believing it also improves our technique.

METABOLIC CONSIDERATIONS

It is now commonly accepted that glucose is the predominant food stuff for the brain. Analyses of arterial and cerebral venous blood of healthy subjects have repeatedly yielded respiratory quotients approximating unity (0.99) which is compatible with the exclusive burning of carbohydrates. It has also been shown that practically all of the oxygen consumed by the brain is used in the complete oxidation of glucose, with an extremely small portion of the glucose going to lactic acid for anaerobic metabolism. It appears that the glucose is not burned directly, but is converted into intermediary products which are then efficiently oxidized. The energy thus derived is not used immediately by the neurones, but is stored in the cells as high energy phosphate compounds, such as phosphocreatine, and adenosine triphosphate, to be released upon demand.[10]

These are but the keystones upon which is now being built the remarkable story of the metabolism of the brain in health and disease.

To presume that we have summarized all that is known about cerebral physiology and metabolism would be a gross error. Nothing could be further from the truth. Ours has been but an introduction to a field of physiological research which already is teeming with new information and promises remarkable discoveries in the immediate future.

Philip J. Hodes, M.D.
3400 Spruce St.
Philadelphia 4, Pennsylvania

We are happy to acknowledge our indebtedness to Dr. Eugene P. Pendergrass, Dr. Bernard P. Widmann, and Dr. O. V. Batson whose valuable

assistance and suggestions have made this work much more informative than it otherwise might have been.

Dr. Widmann sponsored this project in the Philadelphia General Hospital. Dr. Pendergrass reviewed our material at the University of Pennsylvania Hospital and Dr. Batson helped us immensely with the anatomy. We wish also to express appreciation to Dr. S. S. Kety who advised us with respect to fundamentals in physiology.

Dr. Arthur Finklestein, Dr. Samuel Zion, and Dr. George Stein of the Graduate Hospital of the University of Pennsylvania Hospital helped immeasurably. Their interest in our work and their encouragement kept us constantly stimulated.

REFERENCES

1. Adachi, B. Das Arteriosystem der Japaner. Tokyo, 1928, Vol. 1.
2. Browne, K. M., Stern, W. E., and Walker, A. E. Cerebral arterial shunt. To be published.
3. Egas Moniz. L'angiographie cérébrale. Masson & Cie., Paris, 1934.
4. Egas Moniz. Die cerebrale Arteriographie und Phlebographie. In: Handbuch der Neurologie. By O. Bumke and O. Foerster, Editors. Julius Springer, Berlin, 1940, H. 69, 70, Erg. Serie 2.
5. Friedman, A. P., Feiring, E., Davidoff, L. M., and Merritt, H. H. Arteriographic study of effect of drugs on intracranial vessels in patients with chronic headache. *Arch. Neurol. & Psychiat.*, 1949, *62*, 818–821.
6. Govons, S. R., and Grant, F. C. Arteriographic visualization of cerebrovascular lesions. *Arch. Neurol. & Psychiat.*, 1946, *55*, 600–618.
7. Hodes, P. J., Perryman, C. R., and Chamberlain, R. H. Cerebral angiography. Am. J. Roentgenol. & Rad. Therapy, 1947, *58*, 543–582.
8. Kety, S. S. The Quantitative Measurement of Cerebral Blood Flow in Man, Methods in Medical Research, Year Book Publishers, Inc., Chicago, 1948, Vol. 1.
9. Kety, S. S., and Schmidt, C. F. Nitrous oxide method for quantitative determination of cerebral blood flow in man. *J. Clin. Investigation*, 1948, *27*, 476–483.
10. Kety, S. S. Circulation and metabolism of human brain in health and disease. *Am J. Med.*, 1950, *8*, 205–217.
11. List, C. F., Burge, C. H., and Hodges, F. J. Intracranial angiography. *Radiology*, 1945, *45*, 1–14.
12. Padget, D. H. In: Intracranial Arterial Aneurysms. By W. E. Dandy. Comstock Publishing Co., Inc., Ithaca, N. Y., 1944.
13. Riggs, Helen E. Anomalies of circle of Willis. Transactions of Philadelphia Neurological Society, December, 1937.
14. Riggs, Helen E. Anomalies of circle of Willis. Transactions of Neuropathology Society, 1938.
15. Schmidt, C. F. The Cerebral Circulation in Health and Disease. American Lecture Series No. 68. Charles C Thomas, Publisher, Springfield, Illinois.
16. Schultze, O., and Stewart, G. D. Topographic and Applied Anatomy. W. B. Saunders Company, Philadelphia, 1905, p. 37.
17. Shenkin, H. A., Spitz, E. B., Grant, F. C., and Kety, S. S. Physiologic studies of arteriovenous anomalies of brain. *J. Neurosurg.*, 1948, *5*, 165–172.
18. Shenkin, H. A., Harmel, M. H., and Kety, S. S. Dynamic anatomy of cerebral circulation. *Arch. Neurol. & Psychiat.*, 1948, *60*, 240–252.
19. Taylor, E. H., and Haughton, W. S. Some recent researches on topography of convolutions and fissures of brain. *Tr. Royal Academy, Ireland*, 1900, *18*, 511.
20. Wickbom, I. Angiography in post-traumatic intracranial haemorrhages. *Acta radiol.*, 1949, *32*, 249–258.
21. Wislocki, G. B., and Elvidge, A. R. Cerebral vessels studied by angiography. *Res. Pub. A. Nerv. & Mental Dis.*, 1938, *18*, 110–149.
22. Woringer, E. and Gernez, A. L'artériogramme cérébral. *Presse méd.*, 1948, *56*, 881–882.

DISCUSSION*

Dr. Fred J. Hodges, Ann Arbor, Mich. I feel totally inadequate to discuss the physiologic aspects of this question but I am very much interested in the anatomical side.

The importance of communicating channels between the internal carotid bed to the right and to the left of the midline cannot be overemphasized; it is of great practical importance in angiographic diagnosis as well as in carotid ligation when that becomes necessary. The very helpful anatomical analysis to which we have just listened, illustrated with roentgenographic recordings, coincides well with clinical experiences in which contralateral vascular filling is occasionally encountered, sometimes with great diagnostic advantage.

The distribution of vessels from the anterior and middle cerebral arteries, so often confusing in clinical material, has been shown beautifully. Dr. Hodes went to some trouble to show the confusing appearance that occurs when the skull is improperly positioned. Unfortunately, that happens all too frequently, and those of us who have been using cerebral angiography have

* See also further discussion on page 89.

been much annoyed by the confusion that follows.

It is interesting to see anatomical specimens sectioned in the fashion shown separating the middle cerebral vascular bed from the anterior cerebral branches. This would make diagnosis vastly simpler than is the case clinically. We have found that the routine use of stereoscopy is of the utmost assistance in attempting to approach the accuracy which Dr. Hodes has been able to show us.

We have encountered one or two striking examples of the help that is afforded roentgenologists by the presence of adequate communicating arteries, anterior and posterior. In one particular case that comes to mind there was an aneurysm of the anterior communicating artery which was completely invisible in one of two stereoscopic pairs and clearly shown in the second of the stereoscopic pairs. The explanation was quite simple. Two separate injections were used. On the first injection the pressure used was not quite sufficient to offset the pressure on the contralateral side. In the second of the two injections, enough more energy was used in pressing down on the piston of the syringe and some of the opaque material actually crossed, and in crossing showed the aneurysm which might well have escaped notice if one side had been injected alone.

I was particularly impressed by the anatomical material demonstrating the general position of the peripheral branches of the middle cerebral artery which is characteristically peripheral on the lateral aspect of the brain. When we look at an angiogram made in lateral projection there is always a great confusion of vessels and it is obvious, therefore, that it is quite necessary to use frontal projections in order to complete the story.

The authors' observations regarding irregularities in the basilar artery and in the distribution of the vertebral artery fit nicely with clinical experience and also with the fact that vertebral angiography is of far less value clinically than that to be obtained by internal carotid injection.

I quite agree that if it is possible to arrange for postmortem injection of cerebral vessels, it might add considerably to the clarity of autopsy findings.

Vol. 70, No. 1

ROENTGENOLOGIC RECOGNITION OF HABENULAR CALCIFICATION AS DISTINCT FROM CALCIFICATION IN THE PINEAL BODY

ITS APPLICATION IN CEREBRAL LOCALIZATION*

By HERBERT M. STAUFFER, M.D., LEO B. SNOW, M.D., *and* ANDREW B. ADAMS, M.D.
PHILADELPHIA, PENNSYLVANIA

WE HAVE recently observed, in studying encephalograms, a component of the calcification in the pineal region roentgenologically and anatomically distinct from the calcification in the pineal body parenchyma and separated from it by the habenular commissure. With our attention directed to this point, it became apparent that this calcification appears sufficiently frequently and characteristically in routine skull roentgenograms to warrant describing it and directing attention to it as an aid in cerebral localization.

ANATOMY

The pineal body develops as an outgrowth from the roof plate of the diencephalon. The superior margin of this diverticulum becomes the habenular commissure and connects the habenular nuclei, whereas the inferior margin becomes the posterior commissure. In this way, the pineal body is attached at its base by two stalks, one continuous with the habenular commissure and other continuous with the posterior commissure. The base of the pineal in the adult shows a small recess which is a remnant of the diverticulum and is called the pineal recess. The base of the pineal is the posterior limit of the third ventricle. The choroid plexus of the third ventricle attaches to the stria medullaris thalami on either side and to the habenular commissure posteriorly. These attachments of the choroid plexus are called the taenia thalami and the taenia habenulare, respectively.

A posterior evagination of the velum interpositum and the choroid plexus of the third ventricle superior to the habenular commissure produces the suprapineal recess which varies in size in the adult. The inferior layer of this evagination becomes fused with the dorsal surface of the pineal in the development of the suprapineal recess. As a result, connective tissue elements, prerequisite for calcification, are present about the habenular commissure and the stalks of the pineal.

The development of the suprapineal recess with the attachment of the choroid plexus at the taenia habenulare provides an explanation for the presence of calcification lying as a cap over the anterior surface of the habenular commissure. "Habenular calcification" has seemed the simplest appropriate designation for this calcification which we have noted in lateral skull roentgenograms. Among the older anatomists, Retzius[9] and Marburg[6] have described the occurrence of calcification in the taenia habenulare, and it has been mentioned in more recent anatomical contributions.[8] Marburg, among others, has described the developopment of the suprapineal recess and the taenia habenulare, which is reviewed schematically in Figure 1.

To demonstrate the relationships of the cap of habenular calcification to the pineal body and the posterior boundaries of the third ventricle, several histologic preparations of the area were made (Fig. 2). Lateral roentgenograms were first made of blocks of tissue including the pineal region removed from brain specimens. Histologic sections were made from those blocks showing the characteristic habenular calcification. These preparations leave no doubt as to the position and identity of this calcification.

ROENTGEN APPEARANCE AND INCIDENCE

The habenular calcification is recognized roentgenologically in lateral projections of the skull when it appears as a "C"-shaped fleck with the open portion of the "C" directed posteriorly (Fig. 3). The "C" may be more or less tightly closed. When only a small segment is calcified, positive identi-

* From the Departments of Radiology and Anatomy, Temple University School of Medicine and Hospital, Philadelphia, Pennsylvania. Presented at the Fifty-second Annual Meeting, American Roentgen Ray Society, Washington, D. C., Sept. 25–28, 1951.

fication is only possible when the pineal body is distinctly outlined by calcium, either as a peripheral ring or in uniform distribution.

In encephalograms and ventriculograms, the habenular calcification appears to lie in direct contact with the air in the posterior portion of the third ventricle anterior to the habenular commissure, between the pineal recess and the suprapineal recess (Fig. 4).

In order to learn the frequency with which this calcification might be identified in clinical work, 285 "normal"* skull roentgenograms (taken at random from our department files) were examined. Of these, 187 showed calcification in the pineal region; in 40 habenular calcification only was identified, while in 49 both the habenular and pineal calcification could be recognized; in 98 pineal calcification alone was

* Cases with negative roentgen findings and no clinical demonstration of a space-occupying lesion to our knowledge; no cases under ten years of age.

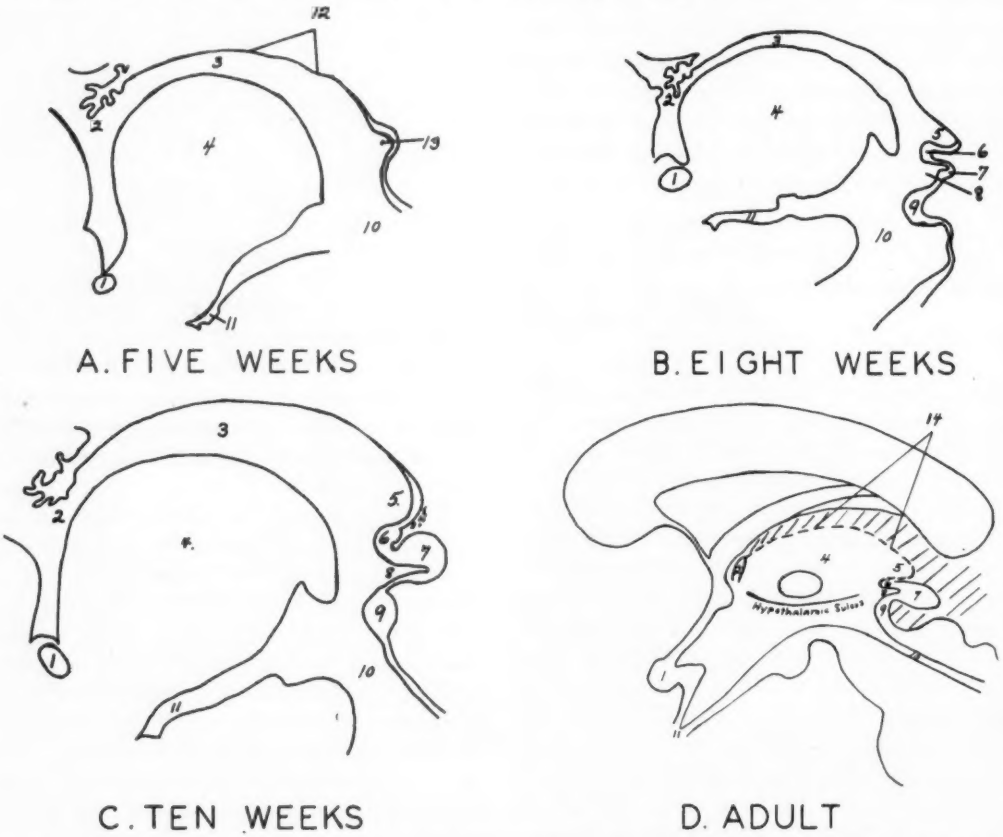


FIG. 1. (*A*) The pineal body begins to develop at about five weeks from the dorsal roof plate of the diencephalon as a diverticulum which enlarges by cellular proliferation. (*B* and *C*) The fibers of the old olfactory system are helping to form the habenular commissure (*6*), relatively much larger than in the adult, which makes its appearance at the anterior, superior margin of the primordium of the pineal. The evagination of the suprapineal recess is evident. (*D*) In the adult the taenia thalami (*14*) are the lateral attachments of the choroid plexus of the third ventricle; the taenia habenulare, over the habenular commissure, is the posterior attachment and site of the habenular calcification.

1. Optic chiasma
2. Foramen of Monro
3. Third ventricle
4. Thalamus
5. Suprapineal recess
6. Habenular commissure
7. Developing pineal
8. Pineal recess
9. Posterior commissure
10. Aqueduct
11. Hypophyseal stalk
12. Roof plate of diencephalon
13. Diverticulum of pineal
14. Taenia thalami

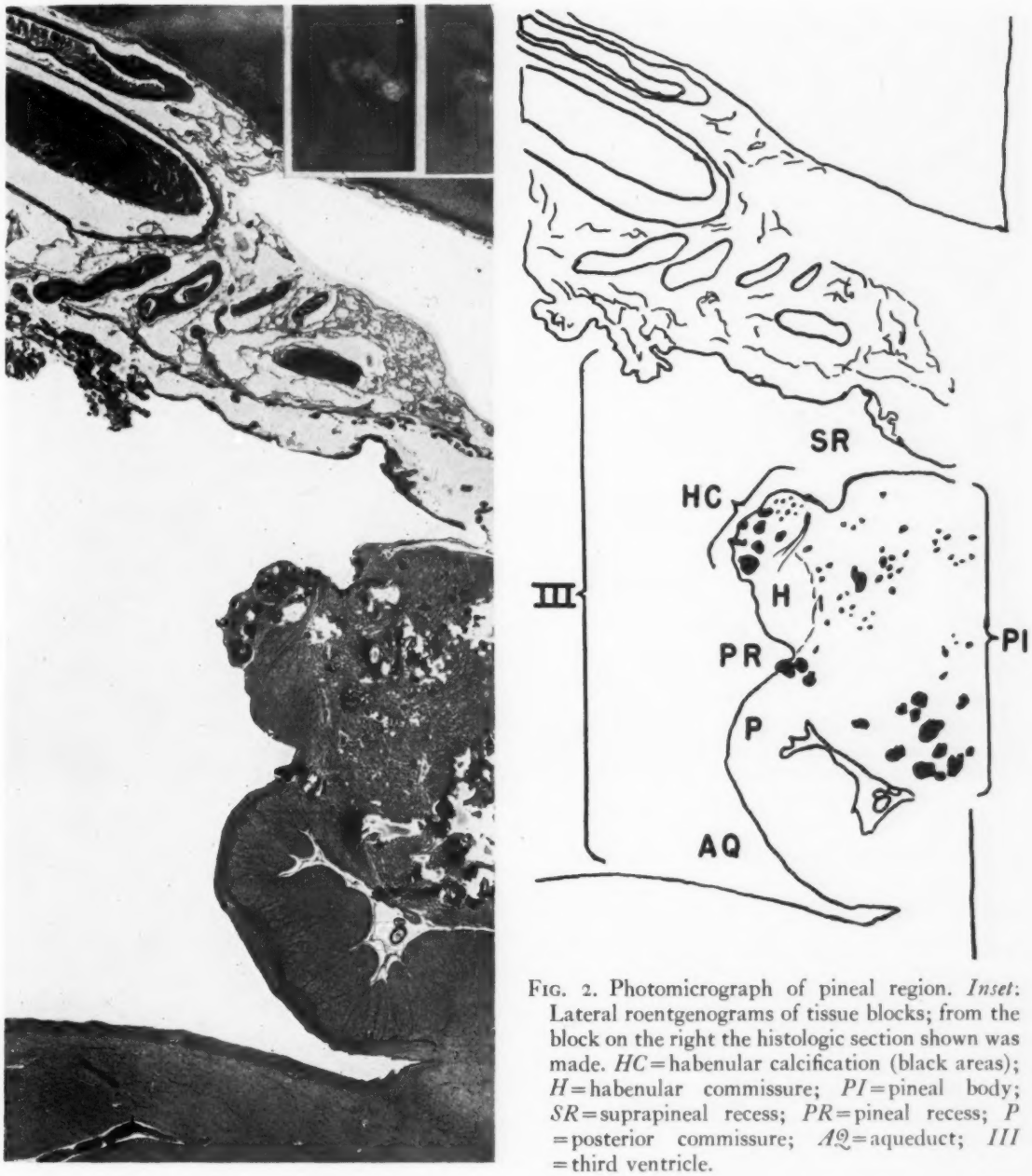


Fig. 2. Photomicrograph of pineal region. *Inset*: Lateral roentgenograms of tissue blocks; from the block on the right the histologic section shown was made. *HC* = habenular calcification (black areas); *H* = habenular commissure; *PI* = pineal body; *SR* = suprapineal recess; *PR* = pineal recess; *P* = posterior commissure; *AQ* = aqueduct; *III* = third ventricle.

noted. Thus, in this series 47 per cent of the cases with calcification showed a characteristic habenular calcification. (In several cases the habenular localization was confirmed in a subsequent air study where only a segment of the "C" was calcified.) The cases in which pineal calcification only was recorded admittedly include a number with flecks of habenular calcification which could not be differentiated from spotty deposits in the pineal body.

APPLICATION IN CEREBRAL LOCALIZATION

The calcification in the pineal region is the most important landmark available for cerebral localization in the routine skull roentgenogram. Since the early observations of Schüller[10] and Naffziger,[7] the value of determining lateral displacement has been obvious. Calcification in the pineal region may often be identified in the lateral projection when it is too faint to be seen in

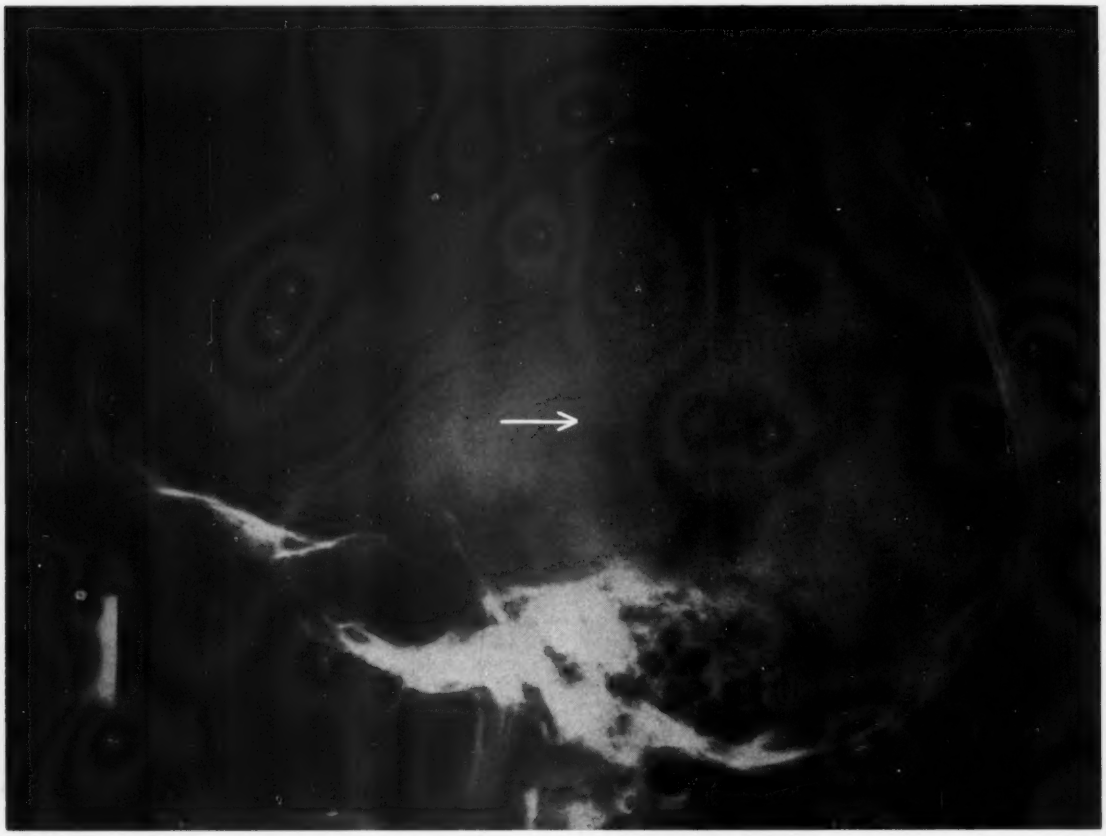


FIG. 3. "C"-shaped habenular calcification alone is visualized in pineal region.

the frontal view. The work of Vastine and Kinney[15] first showed the usefulness in detecting space-occupying lesions of evaluating anteroposterior and vertical displacement in the lateral projection; these authors established normal limits for the position of pineal calcification which have been widely employed in clinical practice. Dyke[1,2] substantiated the work of Vastine and Kinney but advocated adjusting the normal limits 4 millimeters anteriorly since he found that 14 per cent of his cases without verified tumor fell anterior to the original anterior normal limit. Fray[3,4] proposed modifications in the technique of measurement, especially a proportional method which assumes that the distance of the pineal from the frontal bone varies between 55 and 60 per cent of the length of the skull while the pineal-vertex distance varies between 51 and 57 per cent of the skull height. Lilja[5] thoroughly reviewed the problem and expressed his data as ranges of normal variation in the ratios of skull-pineal distance (from various points) to the length and height dimensions of the skull; his approach has the merit of indicating the statistical odds that a pineal in any given location is displaced rather than employing arbitrary limits.

Calcification may be present anywhere throughout the pineal body providing a source of wide variability particularly if only a localized, punctate area is available for measurement.

In our material the pineal calcification averaged 5.4 mm. in length and 3.3 mm. in height; the largest calcification noted was 10 by 5 mm. In the anatomical material of 71 cases, Uemura[14] found an average length (pineal body) of 8.4 mm. and a height of 4.2 mm.; the maximum length was 13 mm.

A further error arises in the separation between the pineal and habenular calcification; in our cases this averaged 5.8 mm., the largest being 8 mm., and the smallest

3 mm. (The center of the visible pineal calcification was always used for measurement.)

It seemed evident that many of these anteriorly situated habenular calcifications have been included in all the published data on pineal localization since no distinction between the two has been reported; Lilja quoted the anatomist Marburg's statement that calcification in the neighborhood of the taenia habenulare is frequent but he does not indicate that the calcification can be recognized roentgenologically. This nonrecognition implies that a normally situated habenular calcification, when it alone is visible, may lie at or above the anterior normal limit according to Vastine and Kinney. We have found this consideration to be of practical value in applying the Vastine-Kinney charts in routine clinical practice. It will be noted that the correction Dyke felt necessary, shifting the normal zone 4 mm. anteriorly, is of similar magnitude to the average habenular calcification-pineal separation which we have found.

The much more specific cerebral localization provided by the habenular calcification does not outweigh the gross variability introduced by measurements from the cranium. We have made measurements similar to those of Vastine and Kinney for the habenular and pineal calcifications separately.* These have been plotted in terms of ratios of calcification—skull distance to the anteroposterior and vertical

* The length was measured as the greatest distance from the inner table of frontal bone to the inner table of the occiput; the height was taken from the inner table of the vertex to the plane of the foramen magnum, the latter approximated by a line from the posterior margin of the foramen magnum to the posterior margin of the hard palate; the target film distance was 44 inches.

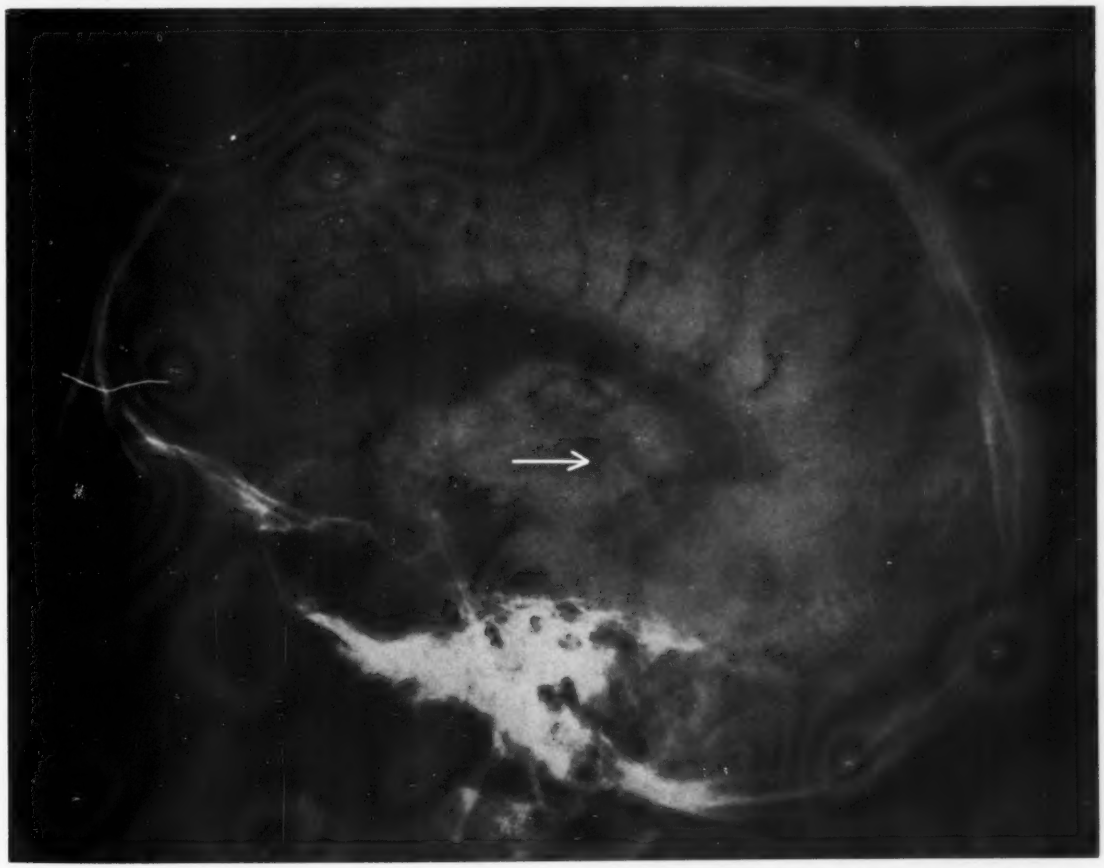


Fig. 4. Encephalogram of same patient as in Figure 3, demonstrating relations of habenular calcification (above posterior commissure and anterior to quadrigeminal plate.)

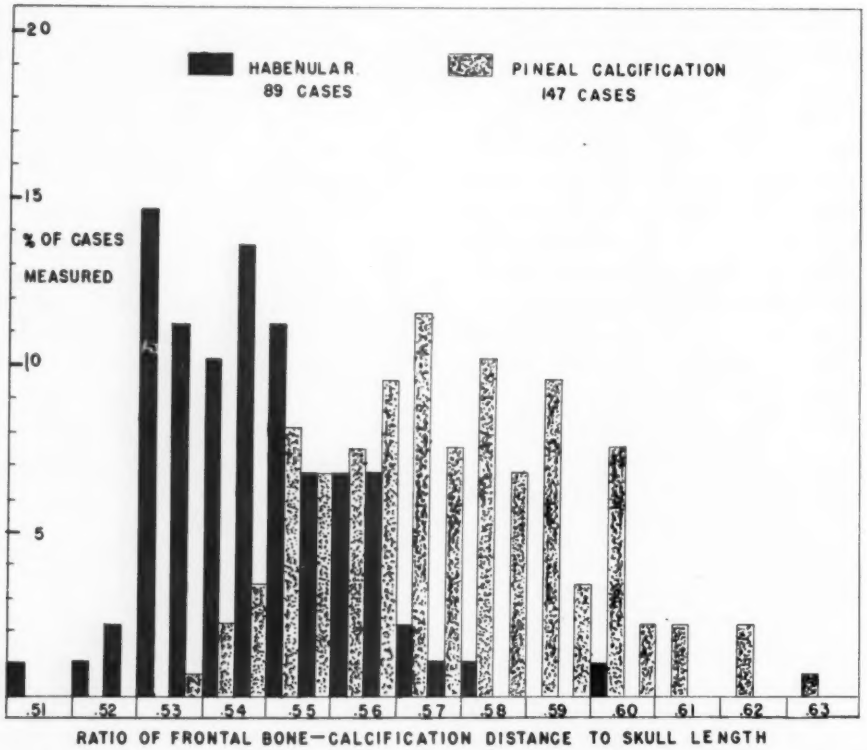


FIG. 5. Chart showing distribution of habenular and pineal body calcifications with respect to the anteroposterior diameter of the skull. The frontal bone-calcification distances are expressed as percentages of skull length. The height of the bars represents frequency in terms of percentage of the total number of calcifications of each type measured.

skull dimensions, respectively[11] (Fig. 5). The range of variation for the habenular calcification lies anteriorly and minimally superiorly compared with that for the pineal. Thus the averages of the ratios are as follows:

Habenular calcification
frontal bone distance to skull length = 55.0%
Pineal calcification
frontal bone distance to skull length = 57.7%
Habenular calcification
vertex distance to skull height = 54.5%
Pineal calcification
vertex distance to skull height = 55.2%

Such separate standards for measuring the pineal and habenular calcifications seem desirable for accuracy; at least, the anterior situation of the habenular calcification should be reckoned with in employing the presently accepted standards.

The highly specific localization of the habenular calcification with reference to surrounding brain structures has been of most immediate importance as an aid in the procedure of stereoencephalotomy as developed and practiced in our institution by Spiegel and Wycis.[12,13] They have employed the pineal calcification as a reference point in producing focal brain lesions with a needle electrode movable in all directions within a frame resting on the skull. Preoperative measurements are made from roentgenograms secured with an auxiliary frame attached to the skull in the same manner. If pineal region calcification cannot be identified, the posterior commissure shown by encephalography is employed as a reference. For example, lesions a few millimeters in diameter have been made in the dorsomedial nucleus of the thalamus as a substitute for prefrontal lobotomy in psychoses, and in the spinothalamic tract at the level of the superior colliculi for the relief of intractable pain. When the characteristic habenular calcification is recognizable, it provides a more

accurate reference point for the required measurements than the much more variable pineal calcification.

SUMMARY

1. The habenular calcification can be recognized in lateral skull roentgenograms as a "C"-shaped calcification in the pineal region. It represents calcification in the taenia habenulare and is separated from the pineal body by the habenular commissure.

2. The characteristic habenular calcification was identified in 89 out of 187 normal skull roentgenograms showing pineal region calcification. Its position averaged 5.8 mm. anterior to the center of the pineal body calcification.

3. In determining possible displacement of the pineal body along the anteroposterior dimension of the skull, allowance should be made for the more anterior situation of the habenular calcification, when the latter is identifiable.

4. The calcification indicates a more constant and better localized anatomical point with reference to neighboring brain structures than does the pineal body calcification. For this reason it is valuable in stereoencephalotomy, which demands the most accurate possible cerebral localization.

Herbert M. Stauffer, M.D.
Temple University Hospital
3401 N. Broad St.
Philadelphia 40, Pennsylvania

REFERENCES

1. Dyke, C. G. Indirect signs of brain tumor as noted in routine roentgen examinations; displacement of pineal shadow. Am. J. Roentgenol. & Rad. Therapy, 1930, *23*, 598–606.
2. Dyke, C. G. In: Diagnostic Roentgenology. Edited by Ross Golden. Thomas Nelson and Sons, New York, 1936.
3. Fray, W. W. Roentgenologic study of orientation of pineal body; comparison of proportional and graphic method in absence of tumor of brain. *Arch. Neurol. & Psychiat.*, 1937, *38*, 1199–1207.
4. Fray, W. W. Roentgenological study of pineal orientation; comparison of methods used in pineal orientation. Am. J. Roentgenol. & Rad. Therapy, 1938, *39*, 899–907.
5. Lilja, B. Displacement of calcified pineal body in roentgen pictures as aid in diagnosing intracranial tumors. *Acta radiol.*, Supp. 37, 1939, pp. 1–183.
6. Marburg, O. Zur Kenntnis der normalen und pathologischen Histologie der Zirbeldrüse; die Adipositas cerebralis. *Arb. a. d. neurol. Inst. a. d. Wien. Univ.*, 1908, *17*, 217–279.
7. Naffziger, H. C. Method for localization of brain tumors—the pineal shift. *Surg., Gynec. & Obst.*, 1925, *40*, 481–484.
8. Quercy, P., Rigaldies, R., Carles, J., and Quercy, D. Sur la région épiphysaire; le sac dorsal; les calculs de l'épiphyse et du sac dorsal. *Rev. neurol.*, 1947, *79*, 401–412.
9. Retzius, G. Das Menschenhirn. P. E. Norstedt & Söner, Stockholm, 1896.
10. Schüller, A. Roentgen Diagnosis of Diseases of the Head. C. V. Mosby Company, St. Louis, 1918.
11. Snow, L. S. Calcifications in pineal region and cerebral measurements: roentgenologic study. Unpublished thesis.
12. Spiegel, E. A., and Wycis, H. T. Principles and applications of stereoencephalotomy. *J. Internat. Coll. Surgeons*, 1950, *14*, 394–402.
13. Spiegel, E. A., and Wycis, H. T. Stereoencephalotomy. Grune & Stratton, Inc., New York, 1952.
14. Uemura, S. Zur normalen und pathologischen Anatomie der Glandula pinealis des Menschen und einiger Haustiere. *Frankfurt. Ztschr. f. Path.*, 1917, *20*, 381–488. Quoted by Lilja.[5]
15. Vastine, J. H., and Kinney, K. K. Pineal shadow as aid in localization of brain tumors. Am. J. Roentgenol. & Rad. Therapy, 1927, 17, 320–324.

FURTHER DISCUSSION OF PAPERS BY DRS. BOUCHARD *et al.*;* CHILDE; MC RAE AND BARNUM; VAN EPPS; HODES *et al.*; AND STAUFFER *et al.*

Dr. Eugene P. Pendergrass, Philadelphia, Penna. I am sure that you agree with me when I say that we have had a perfectly marvelous group of presentations this afternoon. I wish I had time and I wish I were qualified to discuss many of the things that have been brought up.

The work that Dr. Bouchard has presented to us is very interesting. I am very glad that Dr. Wachowski did not agree with him, because whenever there is a difference of opinion, one is more likely to get a definitive answer. I

* The paper by Jean Bouchard, William V. Cone, A. R. Elvidge, and Carleton B. Peirce entitled "An Assessment of Postirradiation Damage to the Central Nervous System," read and discussed in this symposium, has not been received for publication. It is hoped that the paper will appear in a future issue of the Journal.—ed.

know that radiation can produce damage; you do, too. I think it is fortunate that one can give as much a 6,000 roentgens and not produce damage, or damage that is recognized by conventional studies.

A few years ago, Dr. Lawrence Reynolds presented some work on the effect of radiation on brain tissues and reported on a method of observation which possibly should be utilized in this study, especially when autopsy material is available. It is my impression that, with the method he used, one could see much more than one could see on the conventional microscopic section.

The presentation of Dr. Childe is fascinating. I can recall the first time I ever recognized thinning of the skull associated with an underlying tumor. One can get very, very mild thinning of the skull in brain tumors and sometimes so mild, that one overlooks it. I quite agree with Dr. List, that this is a local phenomenon of pulsation. I think it would be difficult to explain otherwise. You will recall Dr. Childe showed a roentgenogram of a mass lesion on the one side and it seemed as though the ventricle on that side was larger than on the contralateral side. I have no explanation for that sort of appearance unless there was a porencephaly of the ventricle or an injury at the time the subdural hydroma was produced.

The work of Drs. McRae and Barnum is magnificant. I learned a lot of things from their comments today. I am quite in accord with Dr. List that the symptoms are probably based on a neurological syndrome and I wonder whether anomalies in blood vessels may not be a factor in the production of such symptoms. Constriction of the dura around the peduncles, which is not seen at the time of operation, may likewise play some role in the production of symptoms.

As far as cerebral angiography is concerned, I would like to say this just as a reminder to ourselves: We are now living in a period when efforts are being made to diagnose intracranial lesions on the basis of counts from radioactive isotopes. I think we have to keep in mind that vessel anomalies may be an important factor in the counts that one gets and not due entirely to a mass lesion underlying the area being investigated.

The observations of Drs. Stauffer, Snow and Adams are, I think, a perfect example of how one can look at roentgenograms for years and fail to develop a curiosity about certain shadows. It never occurred to me that the calcification in the region of the pineal body was anything other than an irregular deposition of calcification in that structure. I feel sure that Dr. Stauffer and his colleagues have received a great deal of personal satisfaction in developing the story that he presented to you today about habenular calcification. No matter whether it provides an opportunity for increased accuracy for localization of cerebral lesions or not, he has certainly added to our knowledge.

DR. WILDER PENFIELD, Montreal, Canada. I am afraid that, unlike Dr. Pendergrass, I can add nothing to this series of papers although I agree with him in admiring the extraordinarily high level of presentation.

In regard to the question of radiotherapy of tumors—the question is whether the roentgen ray injures the brain, and whether it destroys the tumor so as to prolong useful life. I know Percival Bailey very well and I know his laboratory methods well. I also know Dr. Cone and his methods. We work side by side. Dr. Bailey is a good histologist and when he says he has seen evidence of roentgen-ray brain injury, in regard to the case in question we must accept it, of course.

On the other hand, the whole question, of deciding how much good roentgen therapy does the patient, is more important. What we want to know is, not whether there are some histopathological changes in the brain, but whether the patient who has had roentgen therapy lives a happier longer life than the one who has not had such treatment.

This series of Dr. Bouchard and his associates is large and useful. It has one great defect for the purposes of our discussion. The roentgen therapy, in the large majority of cases, is given directly after operative therapy and it is very difficult to distinguish whether good results are due to operation or to radiotherapy.

It is necessary to have controls if we are going to make a judgment, and that means we must have a group of cases that have been operated upon and not given roentgen irradiation so that we may have a control on the ones which have had both. Furthermore, we should have cases in which the roentgen therapy has been used without operation, if possible. The only group in which we have this latter control is the medulloblastomas. In a certain number of such cases radiotherapy has been carried out after simple biopsy without operation. In other cases, we haven't these controls

and the decision of how much use roentgen therapy is becomes very difficult.

Another element that enters into the judgment of the value of radiotherapy is the fact that the neurosurgeon himself, after he has operated on a patient and looked at the sections, decides: "I am not going to refer this case for x-ray therapy. This patient is going to do very well without it." His judgment of course may be right or wrong but it is made on the following basis: if the sections show little cellularity, if there is a great deal of differentiation and formation of neuroglial fibrils, radiotherapy is not recommended. The tumors that have mitotic figures and the ones that are cellular, are invariably referred to Dr. Bouchard for treatment, so that the cases treated form a selected group.

I think that even though roentgen irradiation does produce some cytological change in the rest of the brain, as pointed out by Bailey, these changes may have little effect upon the individual. The question is, did the pateint live longer and more happily as the result of roentgen therapy? Did the destructive effect upon the tumor benefit him in spite of moderate change in the brain itself?

I don't feel that there is an issue of any great importance between Dr. Wachowski and Dr. Bouchard. The question is, whether the patient lives a longer and happier life because of the roentgen treatment. This question can clearly be answered in the affirmative in many cases. If, however, autopsies show that patients die from brain destruction without tumor regrowth, certainly the dosage is too high.

In Dr. Childe's rather extraordinary group of very rare conditions, we must consider what mechanism makes the skull become thin and eroded. A subdural hematoma sometimes results in bone formation. Sometimes the blood absorbs and results in adhesions between the dura and the arachnoid. Now we see this group of cases that Dr. Childe presented in which there is clear fluid on the surface with cranial thinning. In the past I, like some others, have assumed that the fluid was subdural but I am beginning to wonder whether in these cases that he has presented the collection may not be subarachnoid instead.

In the 2 cases that I have explored, there was fine membrane over this collection of fluid and it was not the kind of membrane that is formed by the blood organization of a subdural hematoma. I think that perhaps those cases in which there is erosion of the overlying bone may be the ones in which the fluid has accumulated within the subarachnoid space. As the collection enlarged, it pressed the arachnoid out against the dura.

If that is the case, we must assume that there is a valve arrangement in that portion of the subarachnoid space that allows fluid to enter and doesn't let the fluid run out. I would like to ask Dr. Childe his opinion of this explanation.

In the cases of assimilation of the atlas and the abnormalities around the foramen magnum, I would like to ask Dr. McRae in how many of these cases there has been a previous diagnosis of multiple sclerosis. In my opinion, most patients with multiple sclerosis should have careful roentgen examination of this region.

Seen at autopsy, certainly there is every evidence that the medulla is injured where it angulates over the odontoid process of the axis. From an operative point of view, this is an extraordinarily difficult situation to relieve. Occasionally decompression helps, but actually the problem is to get in front of the medulla and remove the protruding odontoid bit by bit. My associate, Dr. Cone, has been gradually developing burrs to reach it, but it can be done only by special equipment.

With accumulating experience, what was rare becomes commonplace. At the time that Hyndman and I described some of these cases of agenesis of the corpus callosum (1937), Dr. Lysholm of Stockholm told me that the picture was not familiar to him. Now the angel-wing shape in the anteroposterior pneumogram suggests this abnormality at once. The symptomatology which Dr. Van Epps has described must be due to associated abnormalities of the central nervous system and not to the defect in the corpus callosum itself. Surgical section of the corpus callosum is without postoperative symptomatology.

I have learned a great deal from Dr. Hodes' presentation, as I have from all of the papers. I think his proposal of arteriography as a supplementary postmortem technique is excellent. I wonder if, in all cases of discussion of arteriography, there should not be some reference to reactions. Having had a recent death in artiography, I will ask Dr. Hodes if he feels that any reference to its dangers is necessary.

Of course, Dr. Stauffer's demonstration of the habenular calcification is fascinating. It is said that the pineal gland has no function and I think that we have to throw the habenulae in

with it, unless he has some new information regarding it. But I would like to point out an important use of both. They were placed there, I suppose, by the Almighty, for the special purposes of the neurosurgeons so that the radiologist may tell the neurosurgeon exactly where this calcification is and which way it is displaced. Nothing is more helpful to us than that little center of calcification placed in such a strategic position.

DR. CHILDE (closing). I would like to thank Dr. List and Dr. Pendergrass for their discussion. Certainly it seems to me that pulsation, as Dr. List brought out, must have an important bearing on these localized cranial enlargements.

I was interested to hear Dr. Penfield question whether these might not be subarachnoid in origin. Surely the thin membranes that the neurosurgeons have shown me look more like arachnoid than they do like dura. The literature refers to them as subdural hydromas, but as far as I can see, there isn't any good explanation for their presence.

The late Dr. W. E. Dandy, shortly before he died, reported a case of communicating subdural "hydroma." According to his findings, there had been a rent in the arachnoid produced by trauma with a valve type of mechanism, through which a perfectly enormous quantity of subarachnoid fluid escaped over a period of several months. Dr. Dandy painted the arachnoid with iodine and succeeded in closing off the leak.

DR. MCRAE (closing). If I may just answer Dr. Penfield's question, 5 of the 16 cases who had neurological signs and symptoms were diagnosed and treated for multiple sclerosis.

DR. HODES (closing). Having had a death due to diodrast in our department and having had a survey on reactions to intravenous contrast media—sponsored by our department and reported by Dr. Pendergrass, Dr. Chamberlain and Dr. Godfrey—we approach these patients with some trepidation. When this procedure is carried out we always have members of the anesthesiology department with us.

I wish you hadn't asked me this question because probably tomorrow something will happen; but so far, in the brain, we have not had any lasting trouble.

Our Scandinavian colleagues have demonstrated that always, no matter what contrast medium is used, the blood-brain barrier is affected. They have also shown that the brain is affected proportionately to the concentration of the agent used, the amount used and the time it is used. We try to minimize those possible effects upon the blood-brain barrier by flushing the system constantly with saline. We use small quantities of diodrast and occasionally thorotrast (10–12 cc.) and as soon as the injection is made, we flood the hemisphere again with saline.

The fact that thorotrast extravasations in the neck seek the mediastinum and produce symptoms has already been reported. Your attention should be called to the fact that, even though diodrast that extravasates into the neck is rapidly absorbed, there exists for several days thereafter prevertebral soft tissue swelling that is easily demonstrated in lateral films of the neck.

I would like to take this opportunity to ask the radiologists here who have done cerebral angiography and have had a death due to the procedure, to raise their hands. Five hands have been raised, in other words there have been 5 deaths attributable to this procedure.

Finally, I want to thank Dr. Hodges for his gracious comments. I want to thank Dr. Pendergrass and Dr. Penfield for their discussions, also.

DR. CARLETON B. PEIRCE, Montreal, Canada. Dr. Hodes' statement just now, in regard to the character of the soft tissue reaction following injection of diodrast, ties in very interestingly with an observation which we have made repeatedly in regard to its use in excretory urography in that, although you may have a normal excretion in a presumably normal patient with hypermobility of the kidney which the urological surgeon thinks requires fixation, at the time of operation, although it may be seventy-two or ninety-six hours following the injection of the contrast medium, the kidney will be found markedly injected. There is very definitely a chemical inflammatory reaction.

I try to impress upon our students that the use of diodrast, although when carefully controlled is not dangerous to the patient, is not innocuous, and that evidence which Dr. Hodes cites just now is a further indication of the soft tissue reaction to such an agent.

Vol. 70, No. 1

CHRONIC ULCERATIVE GRANULOMATOUS JEJUNITIS AND ILEOJEJUNITIS*

By RICHARD H. MARSHAK, M.D., *and* BERNARD S. WOLF, M.D.
NEW YORK, NEW YORK

TERMINAL or diffuse ileitis is the common form of granulomatous involvement of the small intestine and has been widely recognized since the report of Crohn, Ginzburg and Oppenheimer.[7] However, two other fairly distinct localizations of this process in the small intestine are less well known, namely diffuse ileojejunitis and jejunitis.

In ileojejunitis, there is scattered involvement of segments of ileum and jejunum. In jejunitis, the process is limited to portions of the jejunum. Recurrences following operative procedures for terminal ileitis are not included in this classification. Fairly characteristic roentgen and clinical features are associated with these different distributions.

The etiology of ileojejunitis and jejunitis, like regional ileitis, is unknown. It is not related to sprue, allergy, vitamin or nutritional abnormalities of the small intestine. A specific infecting organism has not been identified.

The present study is based on observations made in 71 cases. Twelve of these were cases classified as jejunitis and 59 cases were ileojejunitis. The basis for inclusion was typical roentgenographic changes confirmed by the clinical picture. In 5 patients, the entire small intestine, including the terminal ileum, was diseased. Every patient with jejunitis had incomplete intestinal obstruction. Sixteen patients with ileojejunitis had incomplete intestinal obstruction with proximal dilatation of either one or more segments. These were classified in a "stenotic" group while 43 were listed as "nonstenotic" ileojejunitis. Six cases of jejunitis were explored. One patient had a side-tracking gastroenterostomy, 2 patients had a removal of the diseased segment of the intestine, and in 3 no operative procedure was considered indicated. Fourteen patients with ileojejunitis have had some form of operative intervention. Six of these cases had a massive resection for obstruction, but 8 patients were explored prior to 1945 without any definitive surgical procedure.

In brief, the symptomatology in both ileojejunitis and jejunitis is that of a gradually progressive disease with fever, loss of weight, abdominal pain, diarrhea and incomplete obstruction. The diagnosis is frequently obscure for many months or years, because the complete symptom complex either does not make its appearance at all or does so late in the life story of the disease process. The presence of fever of undetermined origin may lead to a tentative diagnosis of brucellosis or rheumatic fever. The diarrhea, without careful small intestinal study, may suggest ulcerative colitis. Nine times in this series of cases, these or other diagnoses were made only to be discarded when the true nature of the condition became evident. Fever was a constant feature, though long afebrile periods characterize the relatively quiescent stages of the illness. The range is variable but may reach 105° F. Loss of weight occurs in a high percentage of patients and is especially pronounced during febrile periods. One patient lost 54 pounds in six months. Abdominal pain occurs invariably and more frequently than diarrhea. The pain is diffuse in character, may be predefecatory in time but is more commonly postcibal. Pain is relatively mild until obstruction supervenes; then severe paroxysms and cramps replace the hitherto moderate discomfort. While complete obstruction seldom occurs in ileojejunitis or jejunitis, symptoms are oc-

* From the Department of Radiology, Mount Sinai Hospital; Chief, Bernard S. Wolf, M.D. Presented at the Fifty-second Annual Meeting, American Roentgen Ray Society, Washington, D. C., Sept. 25–28, 1951.

casionally so threatening as to make the use of a Miller-Abbott tube or surgical intervention necessary. Diarrhea, while typical of the disease, was absent in this series in 4 cases. Frequently, the diarrhea is mild with liquid or semisolid stools containing abundant mucus but rarely pus or gross blood. Occult blood, however, is common. Anemia of a secondary hypochronic microcytic nature occurs frequently; rarely it may be of hyperchromic macrocytic type.

Physical examination may be entirely negative. Some of the cases show well maintained nutrition, others give evidence of varying degrees of malnutrition. A mass in the abdomen is occasionally present (9 cases). Clubbing of the fingers was noted in 12 cases of ileojejunitis and 2 cases of jejunitis. The tip of the spleen was palpable 7 times in this series. Either a history of a rectal complication or the actual presence of a perirectal abscess was noted in 8 cases of ileojejunitis. Both internal and external fistulous tracts are less common in this disease than in terminal ileitis; in this series, two external and two internal fistulas were recognized (all in patients with ileojejunitis). One of the external fistulas pointed into the right flank and drained spontaneously, the other into the scar of a previous laparotomy.

Several investigators have divided the clinical course into acute, subacute and chronic stages. However, in this series of cases, any acute stage could be recognized as an exacerbation of a chronic process. We have no case with suggestive acute symptoms and a negative small intestinal series which later showed roentgen changes in the small intestine. Moreover, we have not observed regression in the roentgen changes, although the findings may remain unchanged for a considerable period of time. Some surgeons have reported acute granulomatous inflammation of the small intestine seen on opening the abdomen, but most of the descriptions correspond to acute terminal ileitis rather than to ileojejunitis. Nevertheless, it cannot be denied that acute cases are more likely to come to exploratory laparotomy without having had adequate roentgen examination of the small intestine, and that it may be possible for such cases to go on to spontaneous healing. This possibility is suggested by a case (not included in this series) in whom, at exploratory laparotomy, the surgeon believed an acute granulomatous process was present. However, on re-examination several years later for an unrelated condition, no abnormality was seen in the small intestine.

Since the classical form of ileojejunitis and jejunitis is that of a low grade inflammatory process with episodes of acute exacerbation, it is difficult to correlate such a clinical picture with the abrupt onset of an acute disease. Hadfield,[13] in describing the histopathology of ileitis, does not mention an acute form. Armitage and Wilson,[1] in an excellent contribution to the subject, declare "that it seems very unlikely that this disease begins in this way [*i.e.*, acutely], more likely that the process is insidious from the start and that when the onset is sudden and the history is short, secondary infection has attacked a segment of bowel already the seat of chronic disease." There is a type of enteritis called acute phlegmonous jejunitis but the symptomatology, pathology and roentgen findings are entirely different from granulomatous ileojejunitis and jejunitis. Husebye[15] reported 14 cases in Scandinavia with a 50 per cent mortality and noted that the disease is limited to short isolated segments of intestine without skip areas, the mucosal pattern is jagged and irregular and there is persistent filling of the diseased loops associated with paralytic ileus.

PATHOLOGIC FINDINGS

Gross Pathology. Free fluid was not found in the abdomen in any of the cases that were explored. In the typical case, a mass of thickened, rigid, hose-like intestine, with blotchy red discoloration, is encountered. A striking feature is marked overgrowth of the mesenteric fat on the serosal surface which tends to encircle the diseased seg-

ments. The mesentery of the involved portions of small intestine is greatly thickened, soggy, edematous and always contains enlarged lymph nodes. Skip areas of normal intestine of varying length are characteristic. The serosa proximal to the narrowed areas may also show varying degrees of acute inflammatory reaction. Matting of intestinal loops to each other and the other structures secondary to abscess formation or fistula may be noted.

On opening the intestine, the findings correspond to those reported in regional ileitis by Crohn, Ginzburg and Oppenheimer.[7] The normal intestinal folds are distorted and broken up by a destructive ulcerative process and rounded and blunted by edema, producing a coarsely nodular appearance which in some cases is sufficiently uniform to suggest a cobblestone pattern. A series of small linear ulcerations lying in a groove on the mesenteric side of the intestine is almost always present. The thickening of the intestine is tremendous and is due primarily to a striking increase in the submucosa which is the seat of marked inflammatory hyperplastic changes. The muscular layer is also thickened but to a lesser degree.

Ulceration progresses, may be superficial or deep, with varying degrees of induration and cicatrization. This may give rise to a secondary diffuse inflammatory reaction in the submucosa, muscularis and serosa, this accounting for the abscesses and fistulas. Bockus[3] emphasizes the fact that there is a close relationship between the destructive changes in the mucosa and the extent of increased mesenteric fat. The termination of excess mesenteric fat on the antimesenteric portion of the serosa corresponds to the line of demarcation between diseased and normal mucosa.

The extent of the ulceration varies, leaving behind islands of inflamed mucosa with undermined edges. As cicatrization of the ulcerated areas takes place, the isolated islands of hypertrophic mucosa are thrown up, become prominent and assume a polypoid appearance. At this time, there may be an attempt at healing of the ulcerated areas and the lumen may be lined with a layer of smooth atrophic glistening epithelium. When strictures are marked, the intervening segments of intestine become considerably dilated.

The *histopathology* has been described by Hadfield[13] and while, in his series, only 3 cases of ileojejunitis were reported, further histopathological study has demonstrated the accuracy of his descriptions and the fact that the basic pathology in terminal ileitis, ileojejunitis and jejunitis is the same. Submucosal thickening is the earliest pathological process that occurs and is the result of edema and a widespread hyperplasia of lymphoid and reticular cells. Giant cell tubercles resembling those seen in tuberculosis but without caseation are characteristic. Eventually, the nodules are obscured by more diffuse inflammatory infiltrations with numerous plasma cells and finally by fibrous tissue. Similar changes occur in the mucosa but tubercle formation is not as distinct. Mucosal ulceration is constant and, in later stages, flat regenerated epithelium without glands may be prominent.

TECHNIQUE

The usual barium preparations, preferably without flavoring mixtures, are employed. Twelve to 14 ounces of barium are usually administered, as we feel that demonstration of large portions of the small intestine simultaneously is advantagous since the relationship of diseased segments to one another and comparison with normal intestine is facilitated. Skip areas are more easily identified. Because of the inflammatory reaction, the diseased loops are separated and overlapping of loops is usually not a problem. Overlapping may occur in the ileum and is usually not avoided by smaller amounts of barium. Multiple projections under roentgenoscopic control, with and without graded compression, are more helpful. A barium enema examination for further study of the distal ileum is sometimes necessary. However, this type of examination is not reliable for demonstration of early involvement because of mechanical overfilling and overdistention. We do not use the small intestine enema for the same reason. The cold saline mixtures[26] have oc-

casionally produced peculiar small intestinal patterns in cases subsequently demonstrated to be free of disease by the routine method. We have not hesitated to use the usual amount of barium in patients suspected of obstruction since complete obstruction in this disease is rare. These patients, however, may complain of further distention and discomfort. In every case, however, the barium has passed within thirty-six hours. There may be such marked distention of the loops that administration of small amounts of barium will produce inadequate filling.

The first film is taken one-half hour after administration of the barium and the timing of subsequent roentgenograms depends on the rapidity of passage of the barium through the small intestine. Usually films taken every three-quarters of an hour are sufficient unless considerable obstruction is present.

ROENTGEN FINDINGS

Since the appearance of stenosis of sufficient degree to cause proximal dilatation introduces mechanical changes which are not part of the intrinsic inflammatory process, it is convenient to divide cases into nonstenotic and stenotic groups. While the cases of jejunitis in this series have all been stenotic when first seen, the nonstenotic phase presumably exists and would show changes similar to those to be described in the nonstenotic stage of ileojejunitis. The length of time required for the appearance of stenosis appears quite variable so that no correlation can be made with the duration of the disease or with the apparent degree of activity of the inflammatory process.

FIG. 1. The folds are thickened, blunted and in some areas fused. The contour is irregular. There is rigidity and separation of the loops of intestine. The loops of intestine appear straightened or uncoiled. *Diagnosis:* Ileojejunitis.

The patients in this series have presented themselves for roentgenographic examination with the disease process already well established; it is therefore impossible for us to state whether earlier changes different from those described below exist or can be recognized. We have, however, been able to study early changes in recurrences after side-tracking operations for terminal ileitis. Such changes are similar to those described below in less severely involved segments of intestine in ileojejunitis.

Sussman and Wachtel[23] divide the roentgen findings in this disease into acute, subacute and chronic states. They state that, in the acute stage, differentiation from other abnormalities such as avitaminosis or sprue cannot be made. They describe a patchy segmented distribution of barium throughout the small intestine. The valvulae conniventes appear farther apart. The outline of barium-filled jejunal loops is hazy. The loops of ileum show uneven peristaltic activity and lack flexibility. In the subacute and chronic stages, these authors describe rigidity, ulceration, skip areas, polypoid hyperplasia and pipe-stem appearance of the intestine similar to the late stages of regional ileitis. Weber[25] described the roentgen picture of the acute stage as a flattening of the normally high mucosal pattern.

Some years ago, we encountered 6 patients with roentgen findings interpreted as indicating minimal ileojejunitis. Three were explored by an experienced surgeon and no evidence of inflammatory disease was discovered. Subsequently, food allergy was demonstrated as the possible etiological agent. Two others of the 6 patients revealed a completely normal small intestine on re-examination. The sixth case was one of regional ileitis, in which acute extension of the inflammatory process seemed appar-

ent in the roentgenographic appearance. However, an exploratory laparotomy revealed no evidence of intrinsic disease above the terminal ileum. The roentgen changes apparently were reflex in nature, originating in more distal diseased segments of the ileum. It was because of the diagnostic difficulties in these cases that this series of cases of ileojejunitis and jejunitis were reviewed in order to attempt to establish more definite roentgen criteria of this disease process.

Nonstenotic Phase. The roentgen findings closely parallel the pathologic features described in the previous paragraphs. Early mucosal changes are blunting, flattening, thickening and straightening of the valvulae conniventes. The folds are arranged in a fairly regular symmetrical parallel fashion, appear rigid and are perpendicular to the long axis of the intestine. The folds become thicker, irregular and partially fused (Fig. 1). The lumen and contour become irregular. Occasionally the irregularity of the jejunal contour and valvulae is seen early without distinct blunting or thickening of the folds (Fig. 2). These changes are due to the inflammatory submucosal and mucosal thickening. As ulceration proceeds, a more characteristic and diagnostic pattern is produced. Longitudinal streaks of barium recognizable as ulcerations appear (Fig. 3). As the thick blunted mucosal folds are further destroyed, cobblestoning may be noted (Fig. 4). This has the appearance of rings closely joined on a flat surface and is presumably due to rounding off of the hypertrophic mucosa between the ulcerations. This specific pattern is more common in the jejunum, probably because of the thicker valvulae conniventes in this region. Ulcera-

Fig. 2. There is irregularity of the folds and contour of the distal two-thirds of the jejunum and proximal ileum. A moderate degree of increased secretions and irritability is noted. *Diagnosis:* Early nonstenotic ileojejunitis.

Fig. 3. Longitudinal streaks of barium indicating ulceration are seen. The contour is irregular, with some rigidity and separation of the loops of intestine. *Diagnosis:* Nonstenotic type of ileojejunitis.

Fig. 4. A cobblestone pattern is noted. In other areas the folds are thickened and blunted. The loops of intestine are moderately rigid and somewhat separated. *Diagnosis:* Ileojejunitis.

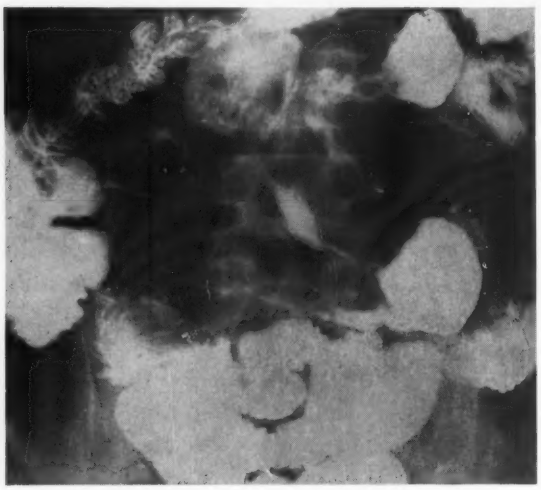


Fig. 5. There are multiple areas of constriction and dilatation. In the constricted areas the mucosal pattern is reticulated. The loops of intestine are separated. *Diagnosis:* Ileojejunitis.

tion continues at the expense of the intervening islands of mucosa, replacing the cobblestone pattern by an irregular network of interlacing streaks of barium. The appearance at this stage has no uniformity or symmetry and is hazy and reticulated (Fig. 5). The denudation of the mucosa is usually incomplete, leaving behind islands of inflamed mucosa which produce multiple smooth defects of varying size (Fig. 6). Their prominence is increased by the narrowing of the lumen due to beginning cicatrical contraction which occurs at this

Fig. 6. There is rigidity, separation of the loops of intestine, numerous small filling defects due to inflammatory polyps and eccentric skip areas. *Diagnosis:* Ileojejunitis.

stage. Finally, one may see the roentgenologic image of a uniform rigid cast-like tube filled with barium and presenting no mucous membrane pattern (Fig. 7). This is similar to ulcerative colitis and represents the stage when scarring and regeneration of the epithelium of the mucosal is progressing. As scarring proceeds, the transition to the stenotic phase occurs.

Coincident with the changes in the mucosal pattern, other characteristic roentgen features occur. The lumen reveals varying

degrees of narrowing. Early, the submucosal thickening and associated spasm is responsible for the narrowing of the lumen. Later, as fibrosis occurs, the narrowing is more marked and finally scar formation leads to the stenotic stage. In the early stages, rigidity of the contour and mucosal pattern is incomplete. Some flexibility or dynamic activity is evident in the change in contour and mucosal pattern during successive roentgenograms. Later, the roentgen appearance is fixed or unvarying, the flexibility is lost, to be replaced by rigidity. Also, early in this disease, the normal serpentine or coiled pattern of the loops of small intestine disappears in the involved segment or segments. These diseased segments appear to be straightened out or uncoiled (Fig. 1 and 8). This finding is probably due to loss of flexibility of the intestinal wall and mesentery as well as longitudinal shortening due to spasm. The loops of intestine are widely separated due to the thickening of the intestinal wall and the increase in mesenteric fat (Fig. 6 and 7). Because of this separation, demonstration of the individual diseased loops is greatly facilitated.

Fig. 7. The loops are rigid and markedly separated. The mucosal pattern appears cast-like. Several small filling defects are noted due to inflammatory polyps. *Diagnosis:* Nonstenotic stage of ileojejunitis.

Fig. 8. Large filling defects. There is a moderate degree of rigidity with areas of narrowing. The loops are separated. *Diagnosis:* Ileojejunitis.

An uncommon but striking finding is the presence of large multiple filling defects (Fig. 8 and 9). This patient, whose history will be given later, was recently explored. Microscopic study revealed the large defects to be inflammatory polyps.

An outpouching of the mucosa between thickened folds occurs in some cases, creating an appearance suggesting diverticula (Fig. 10). This is peculiar in that it seems to affect one side of the intestine and not the other. These pseudodiverticula may be quite large and probably represent small

Fig. 9. Same patient as in Figure 8 ten years later. At this time the lumen of the intestine is narrowed. The filling defects previously described are not as prominent. There is no evidence of an inflammatory mass. *Diagnosis:* Stenotic phase of ileojejunitis.

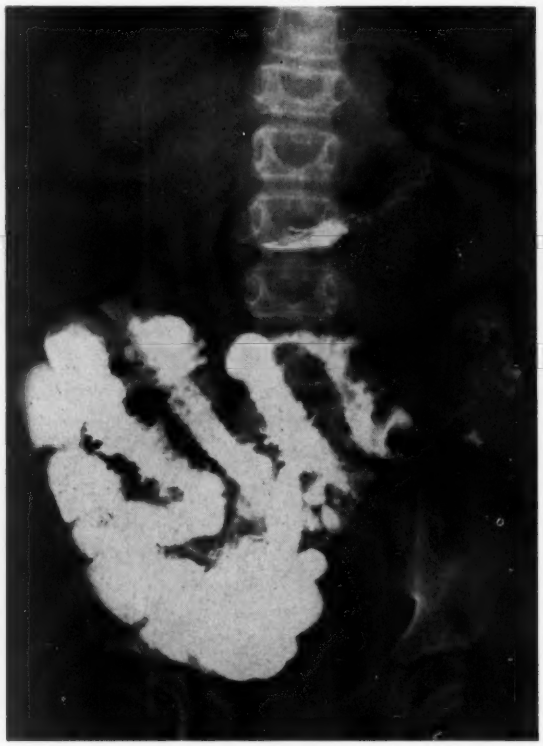


Fig. 10. The diseased loops of intestine are moderately rigid and separated. The folds are thickened and blunted. Pseudodiverticula are present. *Diagnosis:* Ileojejunitis.

eccentric skip areas. Not infrequently, the loops of intestine appear to surround a mass (Fig. 11). Although this may be due to an abscess resulting from perforation, more often it is secondary to the indurated mesentery associated with the marked increase in the mesenteric fat and the enlarged lymph nodes.

The silhouette of the intestine may be hazy. This is due to the fact that the intestine is diffusely ulcerated, contains exudate and excessive secretions and the barium does not adhere to the walls. Despite the increase in intestinal content, the barium mixture remains fluid and homogeneous. Neither agglutination, clumping nor the formation of masses of barium is found in ileojejunitis as contrasted with the findings in so-called deficiency patterns.

Skip areas (Fig. 6), that is segments of normal intestine intervening between diseased segments, represent another characteristic feature of ileojejunitis. The length of a skip area may vary from a few inches

Fig. 11. The mucosa is cast-like with inflammatory polyps. The loop is rigid and narrowed with an inflammatory mass. *Diagnosis:* Ileojejunitis.

to several feet. The length of involvement on a roentgenogram may be quite accurately determined in most cases since the transition of diseased to normal intestine is fairly abrupt.

Segmentation such as is characteristic of sprue has not been observed. When unequivocal segmentation occurs, the diagnosis of ileojejunitis should be suspect.

The following case is illustrative of the nonstenotic phase of this illness.

Case I. P.G., a male, aged thirty-one, was seen in July, 1949, with the chief complaint of diarrhea of eighteen months' duration; the diarrhea consisted of six to ten foul stools a day. During this period, there was a weight loss of 50 pounds. Physical examination was essentially negative. Laboratory examination revealed an elevated sedimentation rate. The white blood cell count was within normal limits. Stool examination was negative for occult blood. Barium enema study revealed no evidence of any abnormality. A small intestinal series performed in October, 1949, revealed involvement of the distal half of jejunum and proximal half of ileum by an inflammatory process. The mucosal pattern was completely altered. In some areas longitudinal streaks of barium indicative of ulceration and the characteristic cobblestone pattern was noted (Fig. 3 and 4). In other areas, the mucosa was blunted, thickened and incomplete. The intestinal wall was somewhat rigid and the lumen in several areas narrowed. Several loops of intestine appeared abnormally separated. During the past year, diarrhea has continued and recently clubbing of the fingers has become evident.

The following patient remained in the prestenotic stage for many years during her adolescence and demonstrated the salient symptom complex and characteristics of this type of ileojejunitis. During her illness, she had one child and, fourteen years after the onset, entered the stenotic phase of ileojejunitis requiring operative intervention. The long follow-up, the multiple and variable diagnoses, the unusual pathologic findings and the transition from nonstenotic to stenotic ileojejunitis are remarkable features in this case.

Case II. E.A., a well nourished female, aged twenty-six, was seen February, 1944, with a history of fever and erythema nodosum of three and one-half years' duration. Her present illness actually began long before. At the age of eleven, following several attacks of abdominal pain, nausea and vomiting, an appendectomy was performed for so-called chronic appendicitis. At the age of thirteen, she suffered an attack of erythema nodosum, which lasted eight weeks, accompanied by intermittent fever. The diagnosis at various clinics was either rheumatic fever or brucellosis. The attacks finally subsided and she was well for three years. In 1940, erythema nodosum recurred, lasted six months, and was accompanied by attacks of severe abdominal pain and fever to 104° F. Her bowel movements were regular and normal. Since then, *i.e.*, for the past three and one-half years, recurrences of erythema nodosum with fever have taken place every few months. She had suffered no loss of weight. Physical examination revealed a severe phlyctenular conjunctivitis, and several erythematous nodules on the right leg and thigh. The abdomen was soft with slight tenderness in the left lower quadrant. The laboratory findings showed hemoglobin 11 gm.; red blood cell count 4.9 million; white blood cell count 4,400, with a differential count of 77 per cent polymorphonuclears, 19 per cent lymphocytes and 4 per cent monocytes. The stools were semisolid, two to three per day, and contained considerable mucus but no blood. Roentgen examination revealed the distal jejunum and proximal ileum to be involved by an inflammatory process characterized by rigidity and straightening of the loops which were widely separated. The mucous membrane pattern was completely altered in a striking fashion. Numerous large filling defects were noted. In some areas, these took the form of intramural projections; in others, they appeared to be primarily intraluminal (Fig. 8 and 9). The lumen was only slightly narrowed except in one area, probably in the proximal ileum, where there was considerable narrowing. There was a suggestion of a mass in the right lower quadrant, and the termnal ileum appeared to be somewhat rigid, narrowed, with absence of a normal mucous membrane pattern. The middle third of ileum appeared normal.

Course. During the years 1944 and 1945, her weight varied between 150 and 164. The stools were about the same, three or four a day, occasionally containing blood, and fever would

return intermittently. In June, 1946, she developed a rectal abscess which discharged frankly purulent material for several weeks and then closed spontaneously. In November, 1946, her second hospital admission occurred. She had suffered sudden recurrence of chills, temperature and abdominal cramps. The abdomen was soft, not tender and no masses were palpated. The patient was treated with streptomycin and the fever disappeared though she still had three mucous stools a day. Folic acid was prescribed for interim therapy. Roentgen examination at the time revealed essentially the same findings as in 1945.

She was relatively well until May, 1948, when she again complained of pain in the legs with ecchymoses over her lower extremities. For one month she complained of epigastric distress and intermittent low abdominal pain with nausea. The patient was not seen again until April, 1950. In the interim there was no pain, fever, diarrhea or any complaints whatsoever. The patient had remarried following a divorce three years previously and was now the mother of a five month old child. Pregnancy had been uneventful and her postpartum period uncomplicated. She complained of epigastric distress, occasional abdominal pain, two to three loose stools a day, soreness in the lower extremities and erythema nodosum of the right knee and left leg. Her bowel habits were normal. Within the next three days, a perirectal abscess was identified and drained spontaneously.

FIG. 12. The entire small intestine is involved with alternating areas of constriction and dilatation. There is separation of the loops of intestine. The mucosal pattern in some areas is cast-like and in others reticulated. The loops of intestine appear to surround masses. *Diagnosis:* Stenotic phase of chronic ileojejunitis.

In July, 1950, the patient, who was now symptom free, was subjected to still another roentgenographic study. At this time, the lumen of the diseased segments of intestine was narrowed with some proximal dilatation. The intestine was rigid and the separation between the diseased segments of intestine more striking. Numerous small, smooth filling defects were noted in addition to the large finger print impressions described previously. In April, 1951, the patient was re-admitted to the hospital with severe cramps, vomiting and a temperature of 102° F. Another roentgen examination revealed essentially the same findings as those described above.

With conservative therapy the above symptoms subsided but cramps soon recurred. Operative intervention was decided upon and on September 18, 1951, a resection of 2 feet of distal jejunum and proximal ileum was performed, including a skip lesion 8 inches in length of terminal ileum. The specimen was striking. The entire mucosa was replaced by very large inflammatory polyps varying in size from 0.5 to 1.0 cm. in diameter. Ulceration and stenosis were prominent in only one area. This lack of striking inflammation and the marked polypoid changes suggested tuberculosis. Microscopic sections, however, revealed no evidence of tuberculosis and confirmed the diagnosis of an atypical form of ileojejunitis.

Stenotic Phase. In the stenotic stage, many of the rigid loops described previously become constricted to a remarkable degree. It is to such areas seen in regional ileitis that Kantor, quoted by Bockus,[3] applied the term "string sign" which has come to be identified as the pathognomonic roentgen manifestation of regional ileitis. It has been described as a thin, irregular, linear shadow, suggesting a frayed cotton string in appearance, that extends through the area of stenosed intestine outlining the lumen of the constricted segment. While

this appearance is occasionally seen in ileojejunitis, it is probably of no special significance, as it is more commonly due to incomplete filling and temporary spasm associated with marked ulceration. The stenotic segments more often resemble rigid pipe stems (Fig. 12, 13 and 14). This appearance is due to a marked thickening and contraction of the wall of the small intestine. The stenosis may extend through 1 or 2 cm., or over long segments. With severe narrowing, dilatation of the proximal intestine may be marked. In many instances, it is difficult to state whether or not intrinsic disease is present in a dilated area. Very often disease is present when a loop of dilated intestine exists between two points of constriction. On the other hand, when there is a single area of constriction with proximal dilatation, disease may not be present in the dilated segment. However, because of retained secretions, secondary inflammatory changes, tension ulcers and muscular hypertrophy, the appearance of the dilated loops may be confused with the alterations seen in granulomatous ileojejunitis. This distinction is of great importance when considering surgical indications. Many cases have not undergone operative intervention because the surgeon was of the opinion that the entire intestine was involved. We believe that extreme dilatation of the intestine for long segments is rarely associated with intrinsic granulomatous disease.

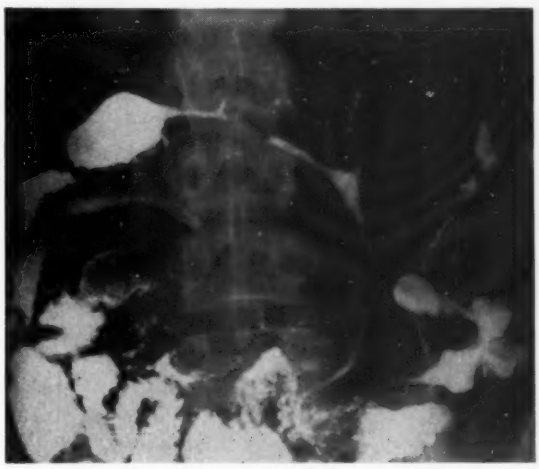


Fig. 13. Long rigid narrowed segments resembling pipe stems with a large inflammatory mass. *Diagnosis:* Ileojejunitis.

Fig. 14. The distal jejunum and proximal two-thirds of ileum show long areas of narrowing alternating with areas of dilatation. The mucosal pattern in the stenotic areas is reticulated. The loops of intestine are widely separated and rigid. *Diagnosis:* Ileojejunitis.

Many of the roentgenographic phenomena observed in the nonstenotic phase of the disease are again noted in the stenotic phase. The mucosal pattern is usually reticulated or cast-like. Small filling defects, inflammatory polyps, irregularly distributed throughout the diseased segments, may be seen (Fig. 11). Skip areas and wide spacing between the segments of intestine are more striking. The loops are rigid and maintain a constant position from film to film. The diseased segments of intestine seem to encircle an inflammatory mass (Fig. 12 and 13). Fistulas, usually involving the distal ileum, may be seen. They appear as short, smooth, fine lines extending from lumen to lumen (Fig. 15). Occasionally these are very difficult to demonstrate, especially when

Fig. 15. The distal jejunum and most of the ileum is involved with alternating areas of constriction and dilatation. A fistula is present in the distal ileum. *Diagnosis:* Stenotic form of ileojejunitis with fistula.

dilated loops of intestine produce overlapping. The fistulas may extend to and penetrate the abdominal wall.

The following case demonstrates the typical history and findings in the stenotic form of ileojejunitis. While gross hemorrhage is not rare, the manner of his death, *i.e.*, by exsanguination, is a rare complication and occurred only once in this series.

Case III. B.P., male, aged thirty, was admitted to the Mt. Sinai Hospital in 1946 with a chief complaint of diarrhea and loss of weight. His present illness began five and one-half years previously when he noticed gradually increasing constipation associated with bright red rectal bleeding. One month later, this was replaced by diarrhea, loose watery stools, numbering ten a day. In a six month period, he lost 60 pounds, his weight then being 140. In 1940, he was said to have ulcerative colitis. In November, 1944, he suffered a period of extreme emotional and physical distress which was associated with increasing diarrhea. He was in very poor general condition.

The laboratory findings were: hemoglobin 13.2 gm.; red blood cell count 4.9 million, and white blood cell count 5,400. A proctoscopic examination revealed edema of the rectal mucosa. A small intestinal series revealed the entire small intestine, starting at the ligament of Treitz, to be involved with multiple areas of constriction and dilatation. The constricted segments appeared as long rigid pipe stems (Fig. 12 and 13). The mucosa in these areas was completely altered. In some segments, the mucosa appeared cast-like with numerous small filling defects; in others, it was reticulated and in the proximal portion of the jejunum there was a suggestion of cobblestoning. The loops were widely separated and appeared to surround masses. In some areas, they appeared as long strands of rope. In the dilated areas, the mucosal pattern was completely altered and these regions contained a considerable amount of secretion. The extent of involvement of the small intestine was very striking. Motility was markedly delayed so that, at the end of eight hours, barium still remained in the small intestine. Because of the poor condition of the patient, a barium enema examination was not performed at this time. After one month of hospitalization and treatment, the patient was discharged, still having three loose stools a day but without blood or pus.

There was no demonstrable fever at any time, though abdominal cramps were frequent, vomiting was occasional and a sense of bloating following meals was a common occurrence. There were never any joint pains. Conjunctivitis was severe whenever the diarrhea flared up but corneal lesions were absent. His frequency varied between two to five stools per day without blood. His weight was 139 pounds.

His past history revealed the following: He had a tonsillectomy at the age of fourteen. In 1939, six months prior to the present illness, he fell a distance of 12 feet, lacerating his scalp and contusing his back. He was not unconscious. He was confined to bed for one week.

His father died of pulmonary tuberculosis in 1944, but the patient was not living at home.

Physical examination at Mt. Sinai Hospital in 1946 revealed a poorly nourished white male. The eyes showed a moderate phlyctenular conjunctivitis; the tongue was smooth. The abdomen was diffusely tender and the tip of the spleen was palpable.

A repeat small intestinal series again revealed the findings described above. The diagnosis was extensive diffuse granulomatous ileojejunitis from the duodenum to the ileocecal valve. Three months later, symptoms recurred and he was readmitted to Mt. Sinai Hospital because of continuing weight loss, abdominal pain and diarrhea. Three weeks later, he was discharged, improved. He went back to work and shortly thereafter experienced an attack of inflammation of the temporomandibular joints; clubbing of the fingers also became prominent during this period. He suffered intermittently from abdominal cramps and vomiting. In 1948 he was hospitalized because of hemorrhage and required several transfusions. In August, 1949, he again suffered several episodes of melena. Pigmentation of the skin developed, but there was no laboratory evidence of Addison's disease. The patient died suddenly of a severe intestinal hemorrhage, ten years after the onset of this progressive form of ileojejunitis.

Autopsy. There was a generalized dark brown pigmentation over the entire body. The small intestine was 16 feet in length. The mucosa was thickened and edematous with a granular and nodular configuration. Numerous areas of constriction of the small intestine were present, with many superficial mucosal erosions. The terminal ileum exhibited the most advanced stages and in some areas the nodularity of the mucosa amounted almost to small polyp formation. The colon was normal but contained many clots. The adrenals were normal. Histopathologic examination of the small intestine revealed infiltration with numerous neutrophils and small round cells. In most areas, the epithelium was absent. The round cell infiltration extended into the submucosa, with extensive scarring. The lungs were completely normal and no evidence of tuberculosis was demonstrable in any of the viscera.

The following case depicts a diffuse stenotic form of ileojejunitis which developed a retroperitoneal abscess and finally an external abdominal wall fistula. The administration of cortisone, other than producing marked subjective improvement, was of no benefit.

Case IV. S.W., male, aged twenty-nine, was seen in July, of 1945, with a chief complaint of abdominal cramps and diarrhea of eight years' duration. In January, 1937, he had developed an anal fistula which subsided spontaneously. In March, 1937, he showed low grade fever of 101° F., with a watery diarrhea, sometimes as many as eight stools a day. In a short period of time, he lost 35 pounds. Despite repeated examinations at various clinics, nothing definitive could be found. During the intervening years, he improved and gained 20 pounds on a restricted diet and prolonged bedrest. In January, 1945, fever recurred and the diarrhea increased. A diagnosis of ileojejunitis was made following roentgen investigation, and he was admitted to Mt. Sinai Hospital.

Physical examination revealed an undernourished individual with mild tenderness in the left lower quadrant of the abdomen. Sigmoidoscopic examination was negative. The hemoglobin was 12 gm.; red blood cell count 3 million, with microcytosis; white blood cell count 3,700, with segmented polymorphonuclears 35 per cent and nonsegmented 23 per cent, lymphocytes 40 per cent and eosinophils 2 per cent. The urine showed a faint trace of albumin and the stools 4 plus guaiac. Penicillin was administered for one week with no change and the patient was finally explored. Ten feet of lower jejunum and upper ileum were involved in an inflammatory process. The intestine was hose-like, with an extremely thickened wall. Biopsies were reported as "fragments of serosal and fatty tissue showing chronic, nonspecific inflammation."

The patient remained well for nine months. In December, 1946, fever and diarrhea recurred, lasted for two weeks, and for a period of six months there were recurrent attacks of fever and diarrhea. He lost 40 pounds. At this time, physical examination revealed moderate clubbing of the fingers and toes. In April, 1948, the patient reported severe attacks of diarrhea and fever with five to six stools every twenty-four hours, lasting several days. In July, 1950, there was, in addition to the diarrhea and fever, soreness in the right flank. On physical examination, there was an orange-sized, tender, firm mass in the right paraumbilical region which was interpreted as a possible retroperitoneal abscess.

A barium meal examination revealed the distal jejunum and proximal ileum to be involved in an inflammatory process characterized by alternate areas of constriction and dilatation, rigidity and separation of the loops of intestine. In the narrowed areas, the mucosal pattern was completely altered. There was a poorly defined interlacing network of barium

Fig. 16. The mid-jejunum is involved with alternating areas of constriction and dilatation. One loop of jejunum is greatly dilated. *Diagnosis:* Jejunitis.

with numerous small filling defects. The mucosa had a reticulated appearance (Fig. 5). A fistulous tract was seen extending laterally from a loop of diseased ileum toward the abdominal wall. Within the dilated loops of intestine, there was a moderate increase in secretions, and an adequate mucosal study was not possible. The proximal jejunum and distal ileum appeared normal.

The patient was placed on chloromycetin and the mass diminished in size. One week later, a tender bulge in the right lumbar area became apparent. Hemoglobin was 11 gm., and a blood smear showed toxic granules. Guaiac test of the stools was 1 plus and the urine revealed a trace of albumin. Chlorides were 92 mg.

Cortisone, 100 mg., was administered per day, and on the fourth day was increased to 150 mg. daily because of an inadequate response. From the very first, there was a marked subjective improvement. His stools became semiformed and were reduced to three to four a day but, despite this, the temperature remained elevated, tenderness in the flank persisted, the hemoglobin declined and his general condition deteriorated. After three days of therapy, he developed leg cramps which were presumed to be due to hypochloremia, but re-examination of the blood chlorides showed them to be 94 meq. per liter. After two weeks of cortisone therapy, his hemoglobin was 8 gm.; red blood cell count 3.1 million; white blood cell count 20,000, with 76 per cent polymorphonuclears and 23 per cent lymphocytes. CO_2 combining power was 62.4 per cent. The temperature remained at 102° F. His appetite was ravenous but there was no concomitant gain in weight. There was considerable bulging in the right flank. In October, 2,500 cc. of greenish pus was evacuated from a large abscess in the right iliac fossa. Cortisone was discontinued. Ten days later, purulent drainage from the operative site persisted and there was a suspicion of gas erupting through the fistulous tract. The drainage became more profuse and fecal material and gas burst through the sinus tract.

On January 17, 1951, he was explored, and approximately 6 feet of terminal jejunum and proximal ileum was resected. The specimen presented a confused mass of small intestine in which there were alternating segments of thickened, narrowed, hose-like intestine with areas of dilated loops. Examination of the constricted segments revealed typical mucosal ulcerations, scarring and stenotic areas of ileojejunitis.

Fig. 17. Greatly dilated segment of jejunum proximal to an area of narrowing in distal jejunum. *Diagnosis:* Jejunitis.

Scattered diffusely along the lumen were polypoid masses from 0.2 mm. to 1 cm. in diameter. In the dilated loops, the mucosa was granular with submucosal lymphoid nodular hyperplasia.

The roentgen findings in jejunitis resemble the roentgen findings in the stenotic phase of ileojejunitis. We have not observed a case of jejunitis in the nonstenotic phase presumably because patients do not present themselves early enough for examination. Every case of jejunitis came under our observation because of obstructive symptoms. On occasion, the dilatation of the loops of jejunum secondary to the areas of constriction may be so marked as to resemble huge sausages (Fig. 16 and 17).

Case v. K.G., white male, aged thirty-one, was seen in April, 1941, complaining of generalized abdominal pain of many years' duration. In 1943, while a member of the Armed Forces, he developed abdominal pain associated with marked distention. Several roentgen examinations of the gastrointestinal tract made at the time were reported as negative, and he was finally granted a medical discharge, with a diagnosis of psychoneurosis.

Despite psychiatric therapy, he had frequent attacks of intense epigastric pain with nausea and slight fever. Diarrhea occurred only rarely. He had lost 57 pounds since the onset of his present illness.

Physical examination was noncontributory. Hemoglobin was 8.5 gm., white blood cell count 10,000, with a normal differential.

Barium meal examination disclosed that the proximal half of the jejunum, starting at the ligament of Treitz, was involved in an inflammatory process characterized by long areas of narrowing alternating with short segments of dilatation (Fig. 18). The mucous membrane pattern was destroyed in the narrowed areas. The third and fourth portions of the duodenum were considerably dilated. The diagnosis was jejunitis of the proximal half of the jejunum. In July the patient was explored. The proximal 18 inches of jejunum was reddened and thickened, with a granular, edematous serosa. The duodenum was considerably dilated, and it was the opinion of the surgeon that there was intrinsic involvement of the duodenum but no biopsy of this region was obtained. A sidetracking gastroenterostomy was performed as no resection was possible.

Six months later, this patient was seen again with a complaint of nausea following meals, relieved only by induced vomiting. Physical examination now showed early clubbing of the fingers and toes. Roentgen examination done at this time disclosed little change in the extension or severity of the lesion. The gastroenterostomy functioned well, and the area of the jejunum immediately adjacent to the stoma appeared normal. He had gained 5 pounds and his hemoglobin was 11 gm.

DIFFERENTIAL DIAGNOSIS

Ileojejunitis. The roentgen characteristics of ileojejunitis are, as a rule, sufficiently distinctive so that differential diagnosis presents no difficulty. Since ileojejunitis usually involves long segments of small intestine, we are primarily concerned in differential diagnosis only with those diseases that also produce diffuse involvement. Sprue has been mentioned most frequently in the literature as being difficult to differ-

Fig. 18. Constricted segments starting at the ligament of Treitz alternating with areas of dilatation in the jejunum. There is considerable dilatation of the duodenum. The mucosal pattern in the constricted areas appears cast-like. *Diagnosis:* Jejunitis with obstruction.

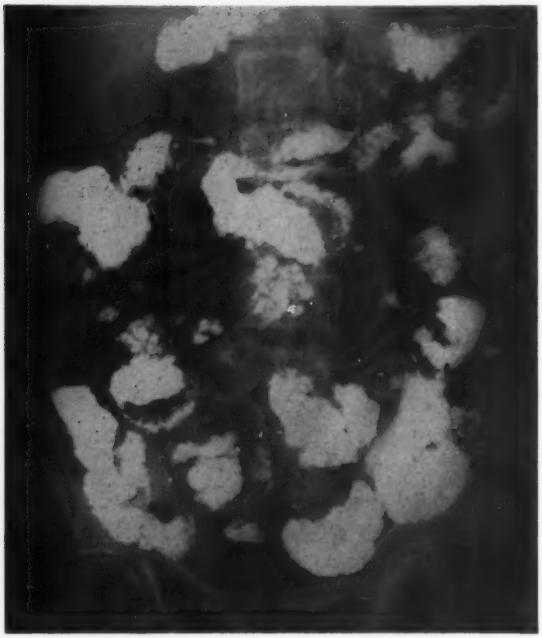


Fig. 19. The entire small intestine is involved. There is marked segmentation, flocculation and increased secretions. In areas there is narrowing of the lumen, the folds are thickened and slightly irregular. *Diagnosis:* Sprue.

entiate from the nonstenotic form of ileojejunitis. In sprue, in contrast to ileojejunitis, the characteristic findings are segmentation, flocculation of barium, in creased secretions, hyper- or hypomotility and dilatation of the intestinal loops (Fig. 19). These changes are evidence of disturbed function and are not inflammatory. Inflammatory changes may occur, but are minimal in degree and extent as compared with the more characteristic changes. Occasionally in sprue, it is possible to alter the small intestinal pattern by the administration of drugs that affect the autonomic nervous system such as prostigmine and banthine or with nutritional factors or by using "colloidal" barium mixtures. We have not observed such induced alternations in ileojejunitis.

There is another group of cases similar in appearance to sprue where a definite allergic factor as the cause of the changes can be identified. These cases have none of the clinical features of sprue. The usual roentgen findings consist of slight segmentation, increased secretions, involvement of most of the entire small intestine, spasm, hyper- or hypomotility and thickened folds (Fig. 20). When thickening of the folds or spasm is prominent, this condition may be confused with ileojejunitis. Straightening and separation of loops, irregularity of the contour, marked mucosal changes and ulceration do not occur.

Henoch's purpura, Whipple's disease, scleroderma, avitaminosis, nephrosis, hypoproteinemia, hypocalcemia, amyloidosis, carcinomatosis and pancreatic insufficiency produce findings which should not be mistaken for ileojejunitis because of the absence or paucity of inflammatory changes.

There still remains a small group of cases with no clinical evidence of any of the diseases mentioned previously, which show diffuse abnormality of the small intestinal pattern. They are characterized by hypermotility, dilatation especially of the jejunum, and thickening of the folds. It is

Fig. 20. The entire small intestine is spastic and irritable. The folds are moderately thickened. There is minimal segmentation with a slight increase in the amount of secretions. *Diagnosis:* Allergy.

possible that some of these cases represent early ileojejunitis. We have never, however, seen such a case develop the characteristic changes described above in ileojejunitis.

In over 90 per cent of the cases, tuberculous enteritis involves the ileocecal region. Occasionally it is diffuse, and then differentiation from ileojejunitis is difficult. Usually in tuberculosis there is more irregularity of the intestinal contour and mucosal markings as compared with a fairly smooth outline of both the constricted and dilated loops of ileojejunitis. Dilatation without stenosis may occur when the loops of intestine are matted together. The valvulae conniventes may become very prominent, coarse and irregular. Often very large filling defects, frequently of the finger-print variety, are noted. These are produced by protrusion of large islands of normal mucosa into the lumen of the intestine following cicatricial contraction of previously ulcerated areas. Recently Bockus, Tumen and Kornblum reported 2 cases in which the small intestinal lesions were impossible to differentiate from ileojejunitis. The same long, rigid, somewhat stenotic segments with a cast-like mucous membrane pattern were evident.

An occasional case of Hodgkin's disease shows diffuse changes of the small intestine, presumably due to blockage of the lymphatic drainage by involved mesenteric and retroperitoneal lymph nodes. There is segmentation, irritability and pressure from extrinsic masses. The segments are small, not dilated, and do not contain increased secretions. Lymphosarcoma may also involve long segments of small intestine, produce narrowing of the lumen or dilatation, destruction of the mucosa and fistulas. Usually, when this occurs, there are other segments where the appearance is inconsistent with ileojejunitis. The presence of masses in addition to small intestinal changes favors lymphosarcoma. We have recently observed a case of lymphosarcoma in a woman, aged fifty-two, in whom a small intestinal series done elsewhere revealed the distal loops of ileum to be rigid and narrowed with numerous fistulas. The initial diagnosis was ileitis. Under observation, a mass of large lymph nodes became palpable in the anterior cervical chain. Biopsy revealed lymphosarcoma. Later, the roentgen features in this case were more typical. Moderately dilated loops of small intestine, with large folds were seen. In addition to these areas, there were large amorphous collections of barium due to deep ulceration of the tumor mass and markedly dilated loops of intestine (Fig. 21).

Fig. 21. Large amorphous collections of barium endo- and exo-enteric. The folds are considerably thickened. Practically the entire small intestine is involved. *Diagnosis:* Lymphosarcoma.

In radiation injury, the involved loops of small intestine may be rigid and reveal a complete absence of a normal mucosal pattern. Fistulas with perforation can occur, and later fibrosis with scarring, stricture formation and proximal dilatation. Separation of the loops of intestine, polypoid defects, skip areas and long smooth stenotic areas, such as characterize the later stages of ileojejunitis, are not observed. No diffi-

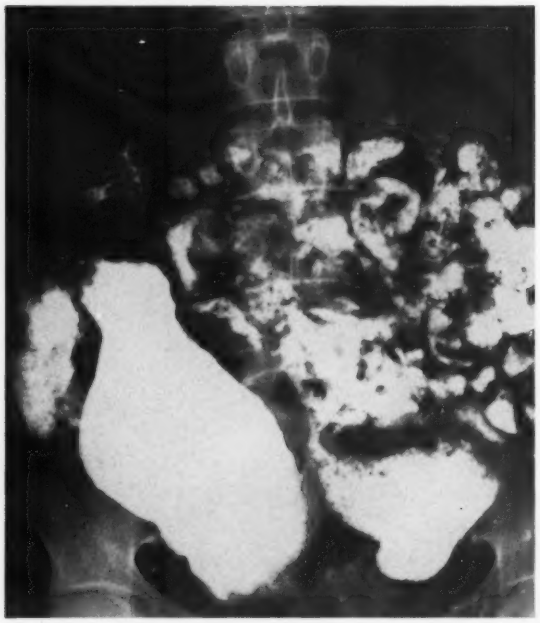


FIG. 22. There is marked dilatation of a segment of ileum. There is considerable thickening of the wall in this area. *Diagnosis:* Lymphosarcoma.

culty can be encountered with a history of radiation therapy.

Jejunitis. Lesions restricted to short segments of small intestine, such as tumors, usually create no difficulty in differential diagnosis because of their isolated nature. However, there are several conditions which may involve a somewhat longer segment which require differentiation from jejunitis.

Lymphosarcoma may cause marked dilatation of a fairly long segment of intestine. The tumor-like thickness of the wall, the presence of an adjacent extrinsic mass, and the absence of stenosis sufficiently marked to explain the dilatation are differential features (Fig. 22).

We have seen 2 cases of Hodgkin's disease involving the jejunum. There was a rigid, slightly narrowed segment several inches in length, slight proximal dilatation and an absent mucosal pattern. However, definite evidence of a well defined extrinsic mass was present.

Infarction of the intestine as the result of intrinsic involvement of the blood vessels or after reduction of a strangulated hernia produces characteristic changes. There is rigidity and slight to marked narrowing of the involved segment with absent mucous membrane pattern. Moderate proximal dilatation is present (Fig. 23). The borders and contour of the lesion are sharply demarcated and the adjacent intestine normal in appearance. These changes progress rapidly with eventual marked stenosis of the intestine.

FIG. 23. A segment of distal jejunum 9 cm. in length is moderately narrowed with proximal dilatation. There is some degree of rigidity and the mucosa appears cast-like. The beginning and end of the constricted segment are abrupt. *Diagnosis:* Infarction of the jejunum.

Foreign body usually produces perforation with an abscess, localized peritonitis and secondary matting together of the loops of intestine. Mucosal changes are not prominent.

COMMENT

We have never seen a case of ileojejunitis show improvement on small intestinal examination. Since such improvement has been reported in ileitis, the possibility of spontaneous regression in ileojejunitis cannot be eliminated. In some patients, though

the symptoms have entirely subsided, cicatrization continued finally resulting in stenosed loops. The identification of the sites of stenosis and the extent of involvement is indispensable information for the surgeon contemplating operative intervention. Many of the patients have required repeated surgery, making localization of the disease process more difficult. Therapy of this condition whether medical or surgical is merely palliative. Within recent years, there have been attempts at massive resection of the involved intestine. Sufficient time has not elapsed for adequate evaluation of this procedure.

CONCLUSION

The present study includes seventy-one cases. Twelve of these cases were classified as jejunitis and fifty-nine cases were ileojejunitis. The roentgen features closely follow the pathological changes and have been divided for the purpose of classification into nonstenotic and stenotic stages. Forty-three cases of ileojejunitis were listed as nonstenotic and sixteen as stenotic. The nonstenotic type of ileojejunitis shows blunting and thickening of the mucosal folds. Occasionally irregularity of the folds and contour is noted. As the ulcerating process proceeds, one of several types of abnormal mucosal pattern is seen. These are designated for convenience as cobblestoning, reticulation and cast form. These mucosal changes are associated with local diminished mobility, straightening of the loops of intestine and later rigidity of the involved segments of small intestine, wide spacing between the loops and, finally, narrowing of the lumen. On occasion, the appearance of pseudodiverticula is produced, and rarely large filling defects due to inflammatory polyps.

The findings most frequently seen in the stenotic type of ileojejunitis are long areas of stenosis resembling rigid pipe stems with proximal dilatation. Disease may or may not be present in the dilated segments of intestine. The loops are widely separated and maintain a fairly constant relationship to one another. The mucosal pattern is usually reticulated or cast-like, and numerous small filling defects may be noted. Skip areas are easily identified, masses are more frequent and fistulas may be demonstrated.

The roentgen findings in jejunitis resemble the roentgen findings in the stenotic phase of ileojejunitis. We have not observed a case of isolated jejunitis in the nonstenotic phase.

Differential diagnosis usually presents no difficulty. On occasion, the roentgen features may be confused with the changes observed in the small intestine in lymphosarcoma and tuberculosis.

Richard H. Marshak, M.D.
1075 Park Ave.
New York 28, New York

The authors wish to express their appreciation to Dr. B.B. Crohn for the use of his material in the preparation of this paper.

REFERENCES

1. Armitage, G., and Wilson, M. Crohn's disease. *Brit. J. Surg.*, 1950–1951, *38*, 182–193.
2. Berman, J. K., Brown, H. M., Foster, R. T., and Grisell, T. L. Massive resection of intestine. *J.A.M.A.*, 1947, *135*, 918–919.
3. Bockus, H. L., and others. Gastro-Enterology, Vol. II, W. B. Saunders Company, Philadelphia, 1944.
4. Brown, P. W., Bargen, J. A., and Weber, H. M. Chronic inflammatory lesions of small intestine (regional enteritis). *Am. J. Digest. Dis. & Nutrition*, 1934, *1*, 426–431.
5. Browne, D. C., and McHardy, G. Primary lesions of jejunum. *J.A.M.A.*, 1940, *115*, 2257–2263.
6. Crohn, B. B. Regional ileitis. *Surg., Gynec. & Obst.*, 1939, *68*, 314–321.
7. Crohn, B. B., Ginzburg, L., and Oppenheimer, G. D. Regional ileitis. *J.A.M.A.*, 1932, *99*, 1323–1329.
8. Crohn, B. B., and Yunich, A. M. Ileojejunitis. *Ann. Surg.*, 1941, *113*, 371–380.
9. Ginzburg, L., and Oppenheimer, G. D. Nonspecific granulomata of intestines (inflammatory tumors and strictures of the bowel). *Ann. Surg.*, 1933, *98*, 1046–1062.
10. Golden, A. Primary systemic amyloidosis of alimentary tract. *Arch. Int. Med.*, 1945, *75*, 413–416.
11. Golden, R. Radiological Examination of the Small Intestine. J. B. Lippincott Company, Philadelphia, 1945.

12. GOLDFARB, S. J. Roentgen diagnosis of lesions of small intestines. *New York State J. Med.*, 1934, *34*, 500–505.
13. HADFIELD, G. Primary histological lesion of regional ileitis. *Lancet*, 1939, *2*, 773–775.
14. HARRIS, F. I. Earliest acute stage of regional enteritis. *Arch. Pediat.*, 1940, *57*, 367–376.
15. HUSEBYE, O. W. On roentgenological diagnosis of "jejunitis acuta phlegmonosa." *Acta radiol.*, 1948, *29*, 71–81.
16. HUSEBYE, O. W. Case of chronic, non-specific jejunitis and stenosis. *Acta radiol.*, 1948, *29*, 516–520.
17. JANUS, W. L. Regional jejunitis. *Radiology*, 1948, *50*, 532–535.
18. JELLEN, J. Regional ileitis. AM. J. ROENTGENOL. & RAD. THERAPY, 1937, *37*, 190–201.
19. KOENIG, A. S., JR., Chronic jejunitis. *Arch. Path.*, 1945, *40*, 187–190.
20. LEHMAN, E. P. Regional enteritis. *Rev. Gastroenterol.*, 1939, *6*, 222–233.
21. OPPENHEIMER, G. D. Non-specific localized granulomatous ulcer of jejunum. *J. Mt. Sinai Hosp.*, 1946, *12*, 1039–1041.
22. SCHEPERS, G. W. H. Pathology of regional ileitis. *Am. J. Digest. Dis.*, 1945, *12*, 97–116.
23. SUSSMAN, M. L., and WACHTEL, E. Granulomatous jejuno-ileitis. *Radiology*, 1942, *39*, 48–53.
24. WARREN, S., and SOMMERS, S. C. Cicatrizing enteritis (regional ileitis) as pathologic entity. *Am. J. Path.*, 1948, *24*, 475–501.
25. WEBER, H. M. Regional enteritis. *Proc. Staff Meet., Mayo Clin.*, 1938, *13*, 545–550.
26. WEINTRAUB, S., and WILLIAMS, R. A rapid method of roentgenologic examination of the small intestine. Dept. Radiology, New York Hospital. In press.

DISCUSSION

DR. FRED J. HODGES, Ann Arbor, Mich. The preliminary reading of this manuscript and the scrutiny of the exhibit which has been up all week, followed by listening to Dr. Marshak's presentation, have excited my admiration for a task well done. The accumulation of the very considerable number of clinical examples of ulcerative small intestinal disease, other than the more common types, bespeaks great interest and industry on the part of the authors.

One wonders, in looking at the truly excellent exhibit, what the early stages of these remarkable disease conditions might have looked like. I talked to him at some length about that and found that he is as much in doubt as all of us must be. Once the lesions are far advanced, as shown in some of the lantern slides, careful analysis results in rather clear understanding of present pathology, but the early developmental stage is quite a different matter. One wonders how often we have actually seen the beginnings of such lesions without recognizing them.

There are two questions that I would like to ask Dr. Marshak. In the patients whose disease was widespread, with profound luminal narrowing, was the transit time of barium greatly modified? Is it true that surgery is recommended by you upon recognition of any of these lesions, or only when stenosis becomes a problem? I am wondering just exactly what the outlook is for patients with this sort of disease and whether you consider surgery to be permissible, advisable, or contraindicated.

Again, thank you very much for presenting excellent material on a subject which has been so baffling to so many radiologists for so long a period of time.

DR. PHILIP J. HODES, Philadelphia, Pa. I should like to add my words of admiration to those already expressed by Dr. Hodges of the Mt. Sinai group and their representative, Dr. Marshak. Their exhibit is beautiful; this paper has been excellent.

There is a pattern seen in these individuals which is probably representative of an earlier stage of the disease. It is a reversible pattern and is seen in persons with zonal areas of more advanced ulcerative disease in the jejunum and ileum. We, too, have seen the full blown process in the stomach and duodenum as well as the jejunum and ileum. The earliest stage is characterized by a very delicate, feathery pattern. The affected segment of intestine is usually wider than normal, and has somewhat the spiked sharp profile of the kymographic records we used to emboss upon charcoaled drums in physiology.

Roentgenoscopically, the intestine is soft and freely movable under the examining hand; yet is has a distinctly abnormal pattern.

With treatment, this peculiar, very faint feathery pattern reverts to normal, or progresses to the more serious forms of the disease.

DR. MARSHAK (closing). I would like to thank both Dr. Hodges and Dr. Hodes for their kind remarks. In answer to Dr. Hodges' first question about transit time in the case with the markedly stenotic loops, it was markedly prolonged, taking between twelve and fourteen hours for the barium to reach the ileocecal valve. We have rarely seen complete obstruc-

tion in this disease, and do not hesitate, therefore, to administer the usual amounts of barium. If you administer a small amount of barium, visualization of the hugely dilated loops of intestine is inadequate and interpretation is difficult. These patients may complain of distention and some pain, but they will eventually pass all the barium.

As for surgery, there are two distinct schools of thought, Dr. Crohn in New York and Dr. Bockus in Philadelphia. I recently had the pleasure of listening to both of them at the last American Gastroenterological meeting. Dr. Crohn stated there was a recurrence rate of 20–30 per cent in his series of cases. Dr. Bockus said there was a recurrence rate of 50–60 per cent. They both concluded that operation for ileitis should be performed after the acute stage is past and there is stenosis. An ileotransverse colostomy with exclusion and no resection of diseased bowel is preferred. When the process is more extensive, involving large segments of small intestine, no surgery is performed unless so much obstruction supervenes that the patients are extremely uncomfortable.

Recently, it has been necessary to perform massive resections in 6 such patients who had multiple fistulas, continuing fever and diarrhea and greatly dilated segments alternating with areas of constriction. Although this procedure is only done as a last resort, it is remarkable how well these patients are with only 2 to 3 feet of small intestine.

In order to determine the earliest roentgen features in this disease we did the following on a series of patients:

After a patient had an ileotransverse colostomy for terminal ileitis, a roentgen examination was performed every six weeks to three months. Thickened, blunted folds and slight irregularity of the contour were the earliest changes noted in the ileum. Ulceration occurs quickly and a reticulated pattern may be a very early finding.

In the jejunum, I have seen what Dr. Hodes described. You saw it perhaps in our first slide. One notes an irregular, thickened, hazy reticulated pattern probably indicative of ulceration. Hadfield, who has done the best histopathological studies on this disease, states that submucosal thickening is the first thing that occurs, and is due to a marked lymphoid hyperplasia. Under these circumstances, it is unlikely that mucosal changes occur without some rigidity and narrowing, irregularity of contour, and slight separation of the loops.

We have not seen a case where the roentgen changes described in the paper have been reversible. Surgeons have told us about it; where they found ileojejunitis and re-explored ten years later for another reason and found no ileojejunitis, but I have never seen a roentgenogram demonstrating this reversibility. The early changes of this disease are probably still unknown and require further study.

ORTHOROENTGENOGRAPHY*†

By G. SCHALTENBRAND‡
WÜRZBURG, GERMANY

FOLLOWING the introduction of stereotaxic operation into modern therapy by Spiegel and Wycis (Philadelphia), Bailey (Chicago), Talairach, Ajuriaguerra and David (Paris) and Monnier (Geneva), the need for orthoroentgenography has greatly increased, since an error of a few millimeters in the placement of a needle in the deeper structures of the brain can have serious results. The usual roentgenograms are shadow pictures and are beset with faults common to such; they show distortions of proportions which are the greater the nearer the source of the roentgen rays is to the object exposed, and the farther the desired portion of the object is from the central ray. Most authors have heretofore sought to avoid these sources of error by placing the roentgen tube as far as possible from the object; for example, Talairach, Ajuriaguerra and David use a distance of 3.20 meters. Since one usually needs roentgenograms taken from at least two, and often three directions, a very large roentgen room is necessitated thereby, with much equipment, over and above that of the operating room itself. Great difficulties arise not only from the point of view of protection from radiation but also of exact centering. The above mentioned French authors use for this purpose an optical centering system, but the adjustment of the tube and the fixation of the head of the patient alone needs at least twenty minutes. Thus, in spite of great expense, only in a narrow region of the skull can a reasonably true roentgenographic projection be attained, whereas in the peripheral regions considerable distortion occurs. Even if one places the tube at a distance of 5 meters, errors of many millimeters cannot be avoided.

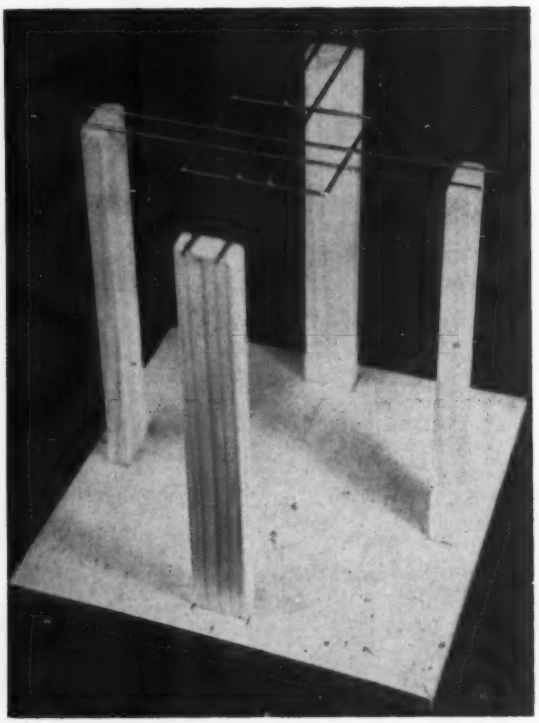


FIG. 1. A structure formed of wires is seen, one quadrangle measuring 1 cm. on each side within another measuring 5 cm. The structure is placed 25 cm. above the base.

Therefore, it occurred to me that it might be desirable to introduce another procedure into the technique of roentgenography, namely to have the roentgen tube move past the object behind a screen with a narrow slit. The slit must be oriented perpendicular to the direction of movement of the roentgen tube. Thus one obtains in the direction of the movement of the tube, an absolutely exact image without any distortion of size. Since one can permit the tube to move over the object, in this case the skull of the patient, in any direc-

* From the Neurological Clinic of the University of Würzburg (Director: Prof. Dr. Georges Schaltenbrand).

† Dedicated to Dr. Percival Bailey on the occasion of his 60th birthday.

‡ I have been greatly assisted in this work by my collaborator, Dr. Nürnberger, and by Dr. Buchtala of the Roentgen Division of the Surgical Clinic, University of Würzburg.

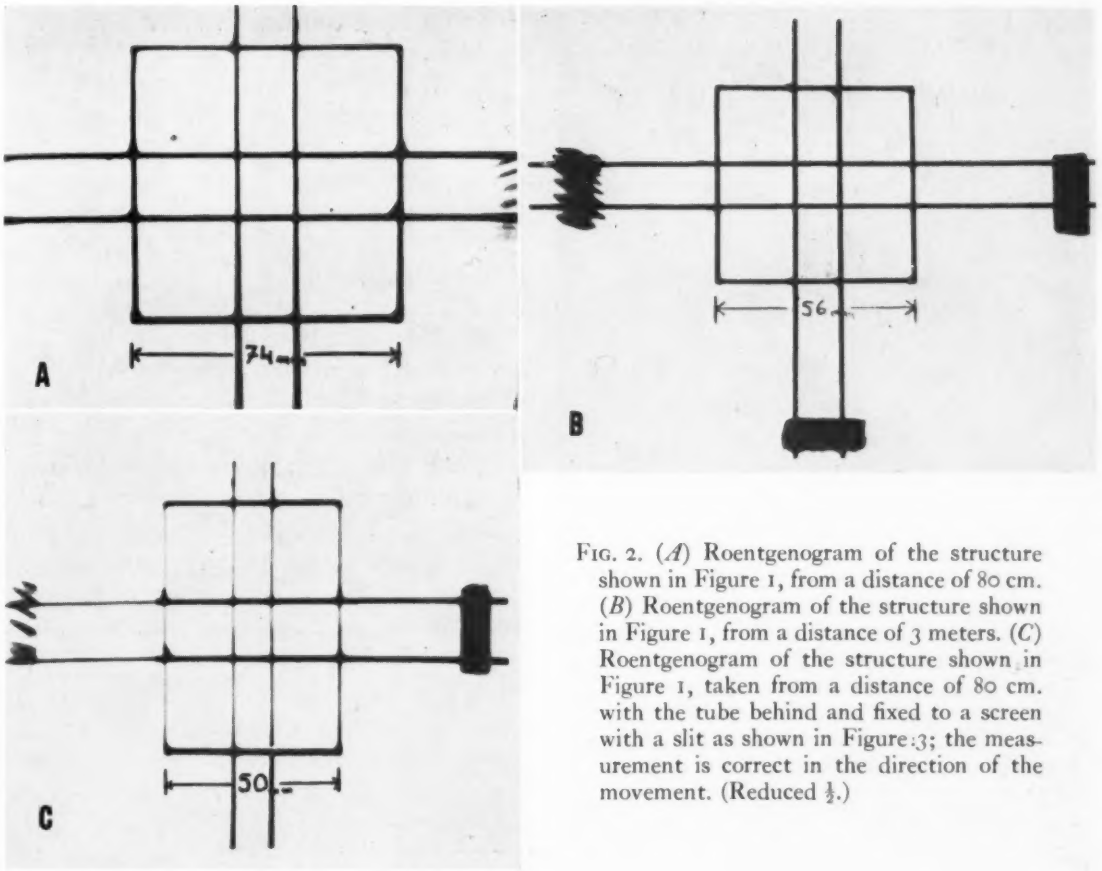


Fig. 2. (*A*) Roentgenogram of the structure shown in Figure 1, from a distance of 80 cm. (*B*) Roentgenogram of the structure shown in Figure 1, from a distance of 3 meters. (*C*) Roentgenogram of the structure shown in Figure 1, taken from a distance of 80 cm. with the tube behind and fixed to a screen with a slit as shown in Figure 3; the measurement is correct in the direction of the movement. (Reduced ½.)

tion desired, one can, for any desired point establish three exact coordinates in space, which can be oriented by any desired system of coordinates, for example from the Frankfurt plane.

The superiority of this procedure over the usual roentgenographic method is shown in Figures 1 and 2. One sees therein a wire frame which consists of two rectangles, one within the other. The outer measures 5 cm. on each side, the inner 1 cm. This frame is placed parallel to the cassette at a distance of 25 cm. Figure 2*A* shows a usual roentgenogram from a distance of 80 cm. and Figure 2*B* a further roentgenogram taken from 3 meters. Even from the latter distance the measurements are not correctly reproduced. Roentgenograms taken by moving a slit across the frame, however, are exact to the millimeter in the direction of movement of the tube (Fig. 2*C*). After a series of experiments, with the kind collaboration of Dr. Buchtala, had convinced me of the superiority of this method over the usual technique, I asked the firm of Siemens Reiniger Werke to build an experimental model in which the roentgen tube could be moved by a motor. With this experimental model, for which I am much indebted to the Siemens Reiniger Werke, I have, with my collaborator, Dr. Nürnberger, taken the following roentgenograms.

Figures 3 and 4 show the provisional apparatus of the Siemens Reiniger Werke which permits movement of the roentgen tube behind a slit in two directions perpendicular to each other. For better demonstration a skull has been shown, fixed in the Bailey-Stein stereotaxic instrument. The other illustrations (Fig. 5 and 6) show arteriograms of the head and roentgeno-

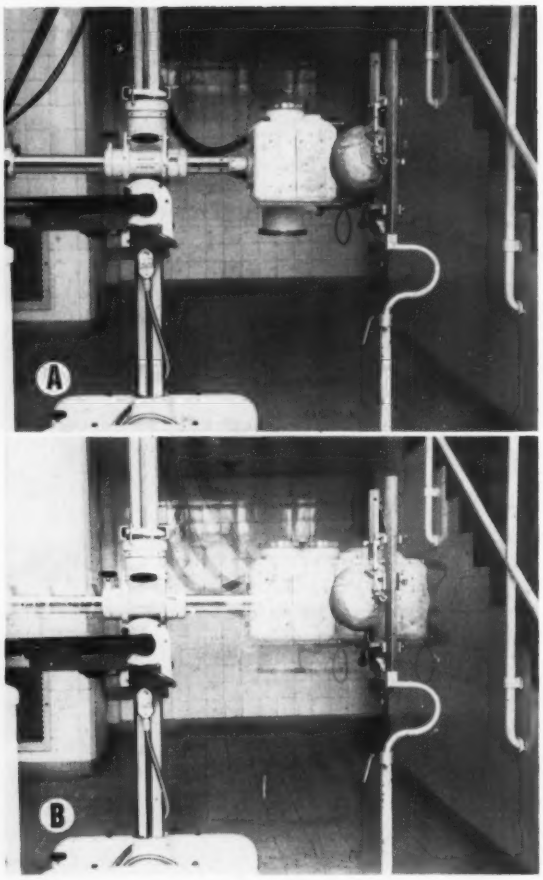


FIG. 3. Apparatus constructed by Siemens Reiniger Werke, arranged to move the roentgen tube horizontally. As a model, a human skull is seen fixed in the Bailey-Stein stereotaxic instrument. (*A*) At rest; (*B*) in motion.

grams after filling of the ventricles with barium suspension and air, both in cadavers. The arteriograms were taken in the anteroposterior projection, with the head lying on its side, while the tube was moved in the horizontal or vertical direction. During the movement of the tube and the slit there was produced, by variation of the frequency of the alternating current and the simultaneous variation in the intensity of the radiation, a vibration visible on the films parallel to the moving slit. One can thus readily see the direction of movement of the apparatus over the film. If one wishes to measure this film, one needs only to draw a line in the direction of this vibration and lay a centimeter ruler perpendicular to it.

The comparison of any two roentgenograms, taken with the direction of movement of the apparatus perpendicular to each other, permits one to recognize how the roentgenogram in the direction of movement is shrunken to its true size, whereas in the direction of the slit the usual recording leads to an irregular enlargement.

Nürnberger, my collaborator, has used the procedure to determine whether with different positions of the head the brain shifts its relations. He measured, for this purpose, the arterial system of cadavers after filling with barium salts. The cadaver was placed in the prone and then in the supine position for twenty minutes, and roentgenograms taken in each position. It could be established by measurements

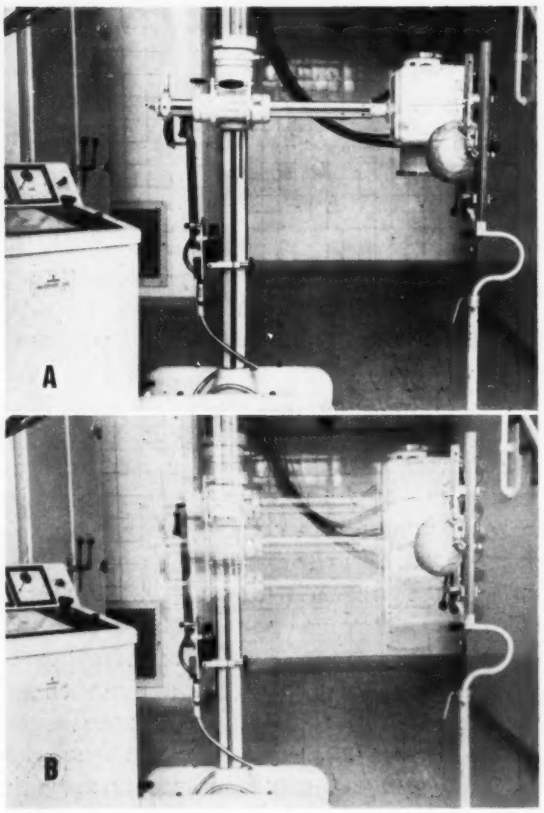


FIG. 4. Photograph of the apparatus arranged for movement of the tube in the vertical direction. (*A*) At rest; (*B*) in motion.

that a shifting of the arterial system, when the skull was unopened, did not occur, at least not more than 0.5 mm. (see Fig. 7).

I believe that the introduction of this procedure of roentgen measurement in roentgenography (orthoroentgenography) of the skull means a real improvement. Of course, the method can be used for other regions than the skull. One can with this apparatus, for example, take orthoroentgenograms of the spinal column, in order to obtain exact measurement of the vertebral bodies which will be very useful in the diagnosis of herniated discs. One can measure the width of the bone marrow in the long bones, and thus obtain information useful for the making of bone grafts. Finally, one can measure the pelvis of women in the obstetrical clinic without the application of compasses and without palpation.

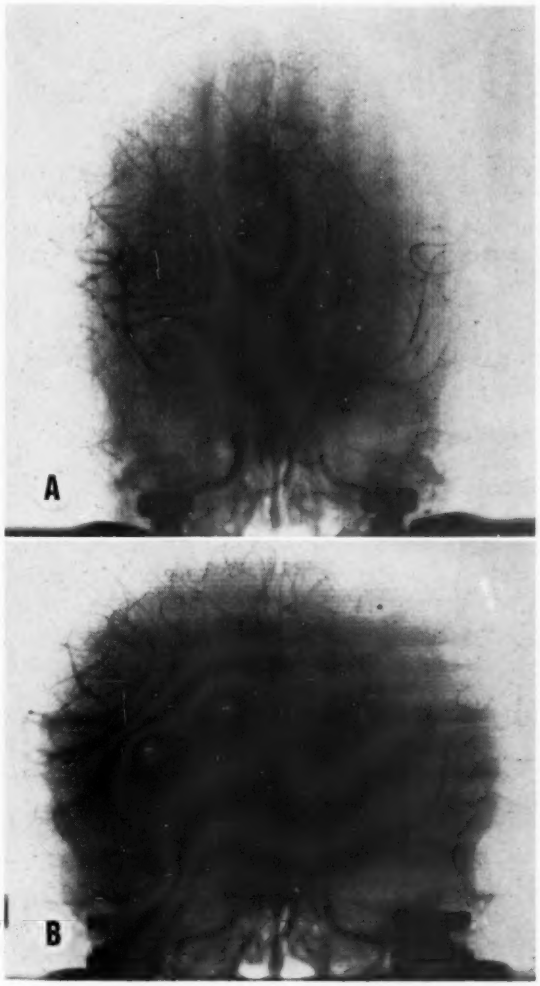


Fig. 5. Arteriograms of a child's head taken with horizontal (*A*) and vertical (*B*) movement of the apparatus. Anteroposterior projection.

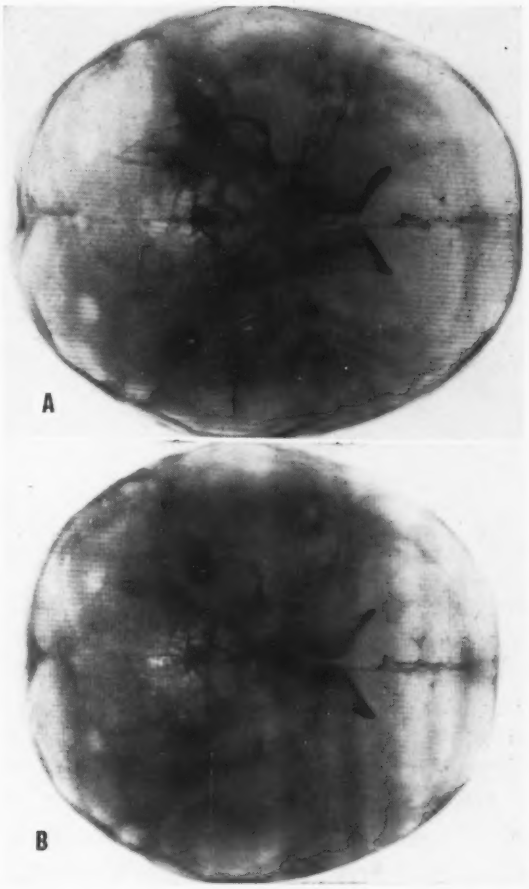


Fig. 6. Axial view of the head after filling the fluid spaces with barium suspension. The slit moved across the head (*A*) and in the long axis (*B*).

This new procedure seemed so excellent and worth while that it meant for us a real disappointment when we discovered that we were not the first to think of it. George Bernard Shaw said, in *The Doctor's Dilemma*, that all medical truths have to be rediscovered every forty years. The firm of Siemens Reiniger found that our procedure was proposed in 1910 by Albers-

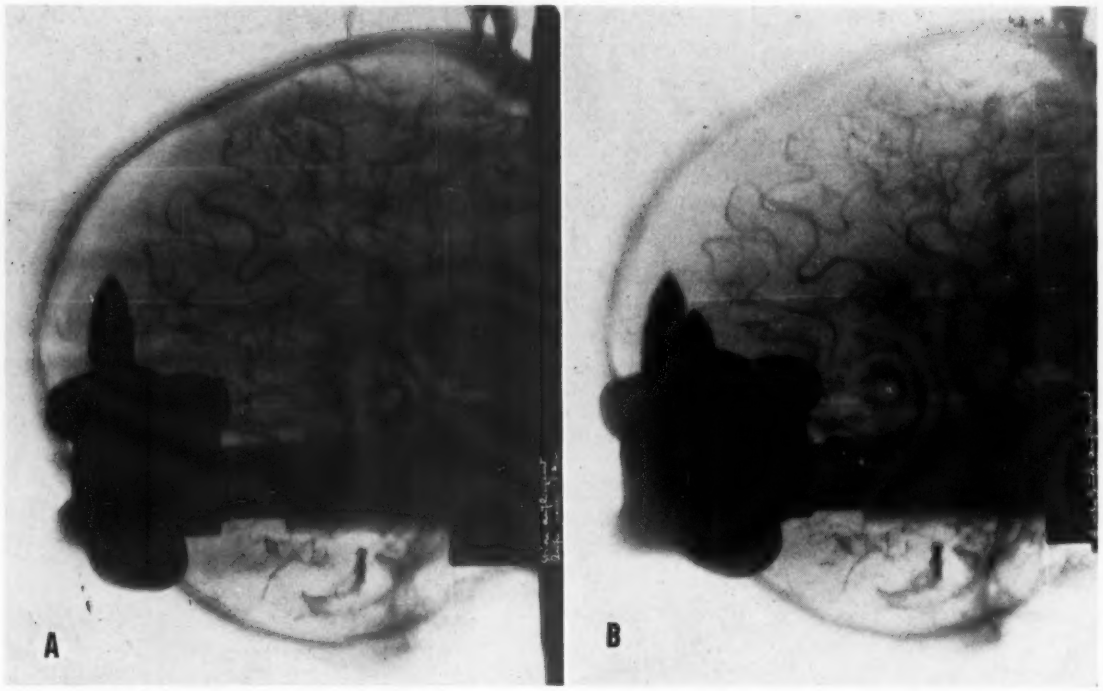


FIG. 7. Arteriogram. Tube moving in the long axis of the skull. (*A*) With the head lying on the forehead; (*B*) with the head lying on its occiput. The measurements of the vascular tree show a shift of no more than 0.5 mm. This is the margin of error of the method.

Schönberg under the name of the "slit screen method" (Spaltblendverfahren). Probably the apparatus of those days was not powerful enough to obtain, with this procedure, satisfactory roentgenograms and further development of a roentgen technique was necessary in order to develop this idea into a fruitful method.

Neurological Clinic
University of Würzburg
Würzburg, Germany

Vol. 70, No. 1

HISTOROENTGENOGRAPHY (MICRORADIOGRAPHY) OF IMPREGNATED CANCER TISSUE

By FEDOR BOHATIRCHUK, M.D., D.M.Sc. (Kiev)
From the Department of Anatomy, University of Ottawa
OTTAWA, CANADA

THE impregnation of histological slides with radiopaque media and historoentgenography (or microradiography) following this have been recommended by Barclay,[1] Bohatirchuk (Bohatyrtschuk),[2,3] Clark,[4] Lamarque,[5] Mitchell,[7,8] and others.

The selective adsorption of these media by some tissue elements permits easy detection in the microradiograph, as the impregnated tissues reveal better their roentgen-ray morphological differences than the nonimpregnated do. But references in the world literature on this interesting subject are scarce. It is not known why tissue elements are electively stained by radiopaque media. Only a few authors[1,3,6] identify the contrast media used in their studies. There is also lacking any detailed description of morphological features of impregnated tissues both in the normal and in the pathological.

MATERIAL AND METHOD

In our work we have attempted the impregnation of histological sections of cancer tissue: both experimental material (Brown-Pearce rabbit carcinoma) and human postmortem or postresection material. At first the kidney, liver and lung with metastases were chosen. Later the following specimens of human cancer were investigated: (a) scirrhous carcinoma of the breast; (b) papillary serous cystadenocarcinoma of the ovary; (c) adenocarcinoma of the rectum; (d) adenocarcinoma of the ovary; (e) secondary squamous cell carcinoma in the neck (primary site is unknown); (f) secondary carcinoma of the axillary lymph nodes (primary tumor—breast).

The following technique was adopted: The tissues were sectioned either (1) following twenty-four hours in neutral formaldehyde solution, or (2) several hours after death (or operative resection) without any previous fixation. Sections of 30–75 microns were cut with the freezing microtome. Following this, the sections were placed in thorotrast (colloid dioxide sol of thorium, 25 per cent of thorium). Two samples of thorotrast were used: (1) made in Germany by Heyden (Radebeul b. Dresden) and (2) made in the United States by the same company. Both samples produced approximately the same impregnation. At first, the sections were kept in thorotrast for twenty-four hours but it was found later that sufficient impregnation was also produced after four and even after two hours. It was only necessary to turn the sections over periodically. After the impregnation the sections were mounted on aluminum foil slides of various thickness (0.00003 or 0.00045 inch were the most translucent for roentgen rays).

Mounted sections were dried between two microscope slides, although the sections could be radiographed when wet. If wet, they were separated from the emulsion by the aluminum slide. Such microradiographs permitted only a low magnification and therefore they were used merely for orientation. After drying, the sections were placed in contact with the emulsion and subsequently roentgenographed. It must be noted that the closer the contact between the section and the emulsion, the sharper is the detail of the historoentgenogram and the higher the magnification that may be obtained. The best contact between the section and the emulsion was achieved by dismounting the dried sections from the aluminum foil, placing them directly on the emulsion, and pressing them to the emulsion with a thin cellophane film fixed

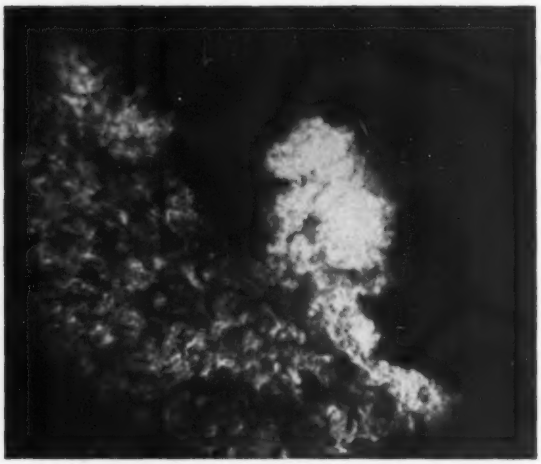


FIG. 1. Historoentgenogram of kidney with metastasis. ×30.

on some metallic frame or ring. The dismounting was easily done with the thick sections (50–75 microns) but sometimes it was also possible with the thinner specimens. There were some tissues (*e.g.*, lymph nodes, spleen, etc.) which could not be cut after freezing because of their brittleness. These tissues were hardened before cutting by passing them through gelatin. In our studies we also prepared control histological slides using the usual methods of staining.

Special fine grain emulsions were used for the historoentgenography. The best

FIG. 2. Historoentgenogram of kidney metastasis (top of picture). ×90

were No. 548 and 649 plates by Eastman Kodak made in the United States, and Lippmann films made in Belgium by Gevaert. These emulsions easily allow a magnification up to 200 and in some cases even more.

The plates or films with mounted sections were placed in the special boxes and roentgenographed with very soft roentgen rays at 10–12 kv. We used for the historoentgenography the beryllium window tube made by Machlett in the United States. This tube generates very soft and (what is still more important) homogeneous radiation and may be chosen with a

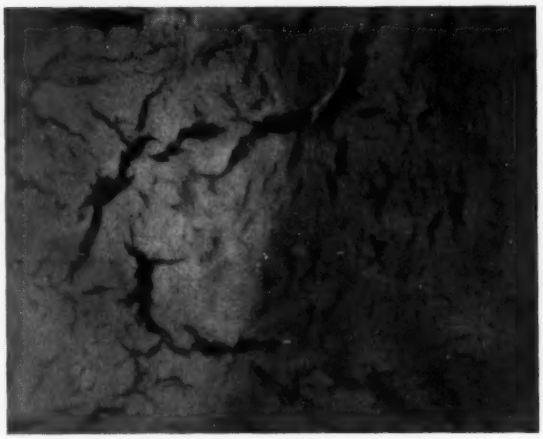


FIG. 3. Historoentgenogram of liver with metastasis (white). ×30

very small target focal spot. With all the factors mentioned above, the exposure time was from four to fifteen minutes, depending upon the distance, kilovoltage, milliamperage and the thickness of the section.

RESULTS

A. *Experimental Material.*

Kidney metastases of Brown-Pearce carcinoma in rabbits were impregnated with thorotrast quite visibly. In Figure 1 we see the metastasis (white) at the periphery of the organ impregnated with thorotrast. The difference in the roentgen-ray absorption between the cancerous and normal tissues is well seen. At higher power (Fig.

2) some structure may be distinguished in this impregnated tissue. Here many small white stripes representing the small tumor vessels are seen distinctly; the white spots without definite borders show the impregnation of cancer cells. There are many black areas showing lack of roentgen-ray absorption. They probably represent necrotic masses. The metastasis is surrounded by a zone of compressed parenchyma. Many thorotrast-laden fibers are seen in this zone. The histological slide of the same metastasis shows much poorer vascularization than the historoentgenogram does. This is probably explained by indistinct

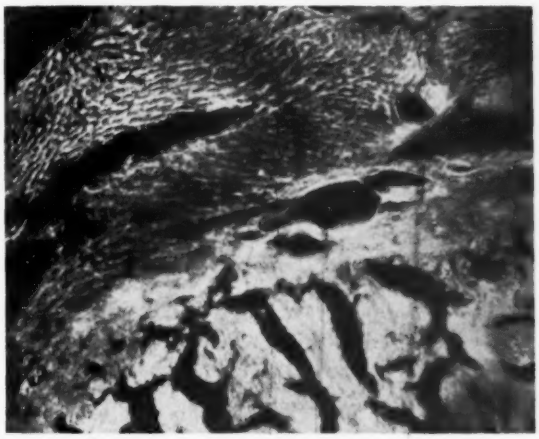


Fig. 4. Historoentgenogram of liver with metastasis. ×90.

structural differences of small tumor vessels in histological slides while each vessel impregnated with thorotrast is well seen in the historoentgenogram.

Liver metastases of the same tumor were selectively impregnated. The low power historoentgenogram (Fig. 3) shows the border between the cancer tissue (white) and the normal tissue distinctly. At higher power (Fig. 4) the structure in the impregnated cancer tissue may be distinguished, *i.e.*, many small vessels, filled with cancer cells, areas of necrosis. On the periphery of the metastasis the invasion of cancer cells into normal parenchyma is seen. In the area of metastases the liver parenchyma is partly destroyed and replaced by cancer cells but it may be recognized in some

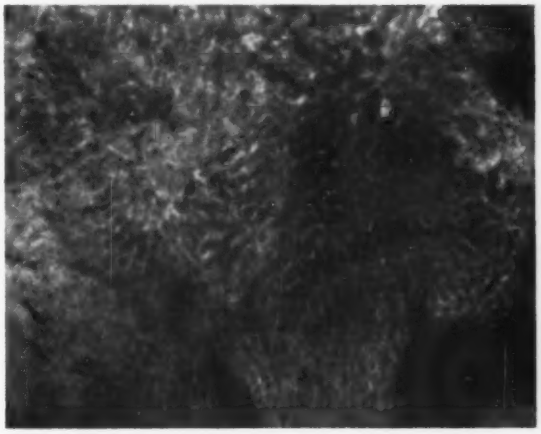


Fig. 5. Historoentgenogram of liver with metastasis. ×90.

tumor sections. The increase of thorotrast adsorption may be seen in seemingly normal liver parenchyma, as is shown in Figure 5. These areas correspond to the beginning invasion of cancer cells seen in histological slides.

Lung metastases (Fig. 6) of Brown-Pearce tumor were impregnated quite considerably. The vascularization of the tumor is well seen. The control histological slide shows that thorotrast is adsorbed by all tumor elements; it is seen in cells as well as in stroma.

B. *Human Material.*

Cancer tissue of the breast tumor (scirrhous) adsorbs thorotrast more than the normal tissue does. Thorotrast is seen in all tumor elements. The tumor tissue is distinctly distinguished from the normal

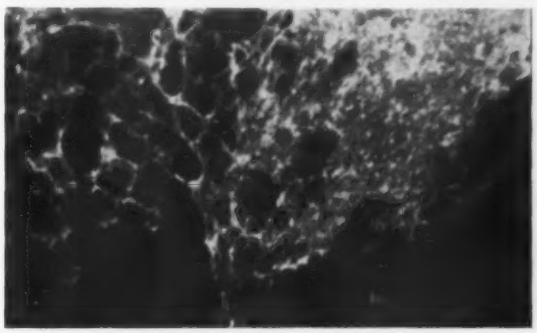


Fig. 6. Historoentgenogram of lung with metastasis. ×45.

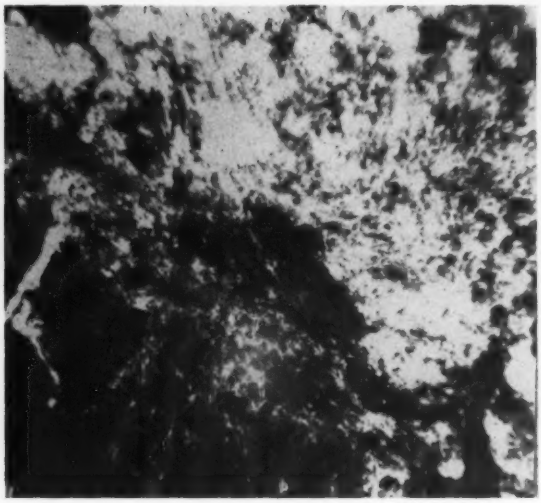


Fig. 7. Historoentgenogram of scirrhous carcinoma of the breast. ×30.

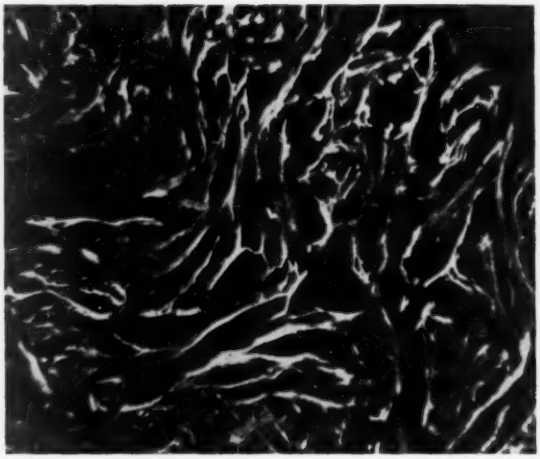


Fig. 9. Historoentgenogram of the scirrhous stroma. ×150.

(Fig. 7). Stromal debris is well seen in Figure 8. At higher power some stromal bands reveal uneven spots (Fig. 9). The comparison with histological slides shows that these spots are caused by thorotrast adsorbed by cancer cells.

Papillary serous adenocarcinoma of the ovary shows the same preferential adsorption of thorotrast by tumor elements (Fig. 10). The histopathologic and historoentgenographic pictures are very similar and they allow easy identification of all these elements.

Adenocarcinoma of the rectum does not adsorb thorotrast so selectively as other specimens, but the staining is quite sufficient to produce a typical morphological picture, very similar to the histopathologic one (Fig. 11 and 12).

Adenocarcinoma of the ovary reveals the same preferential thorotrast adsorption as in papillary carcinoma of the second case (Fig. 13). The staining of cancer cells is especially conspicuous.

Secondary squamous cell carcinoma of the neck shows a typical morphological picture of tumor cell invasion. Thorotrast adsorp-

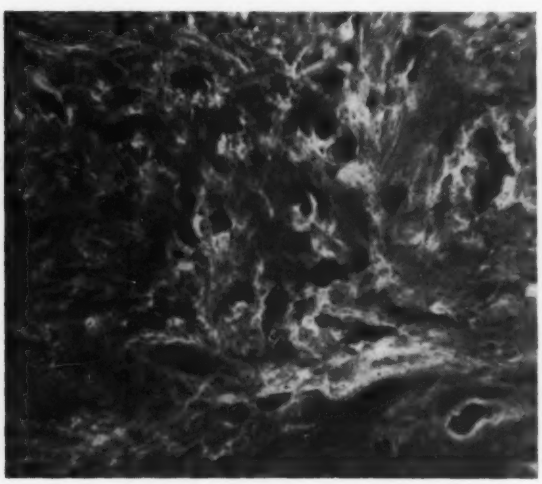


Fig. 8. Historoentgenogram of the scirrhous stroma. ×90.

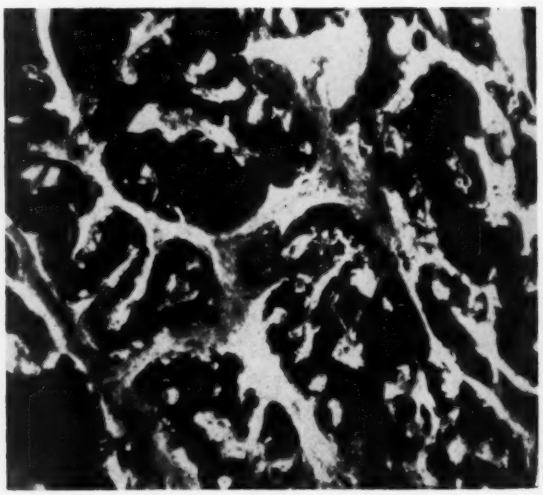


Fig. 10. Historoentgenogram of papillary serous adenocarcinoma of the ovary. ×90.

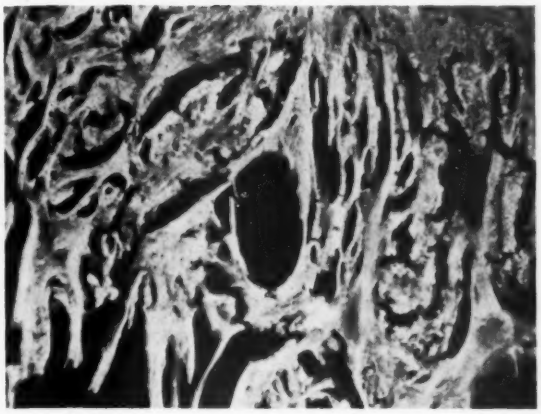


Fig. 11. Historoentgenogram of adenocarcinoma of the rectum. ×90.

tion is increased (Fig. 14).

Secondary carcinoma of the axillary lymph node reveals a very poor adsorption of thorotrast. Only areas of increased vascularization are seen (Fig. 15). Either the electrical charges of lymph node and thorotrast are identical in the case of cancer metastasis or some other factors cause this poor adsorption. We tried to neutralize the supposed negative charge of the node by preliminary bathing of sections in 10 per cent sodium chloride. The staining after such bathing becomes more definite (Fig. 16).

DISCUSSION

Thorotrast injected into the blood of the living is adsorbed in the normal case by elements of the reticuloendothelial system (especially by those of the liver and the spleen). Our experiments show that the same affinity between these elements is present after death. We found also that cancer tissue adsorbs thorotrast more than normal tissue. A historoentgenogram of the liver with metastases is very typical; here besides the usual thorotrast distribution along the liver capillaries we see the increased adsorption of it by metastatic tissue (Fig. 4).

Due to this fact even beginning cancerous invasion may be detected in the historoentgenogram. This means that in some cases the historoentgenogram may even acquire diagnostic value.

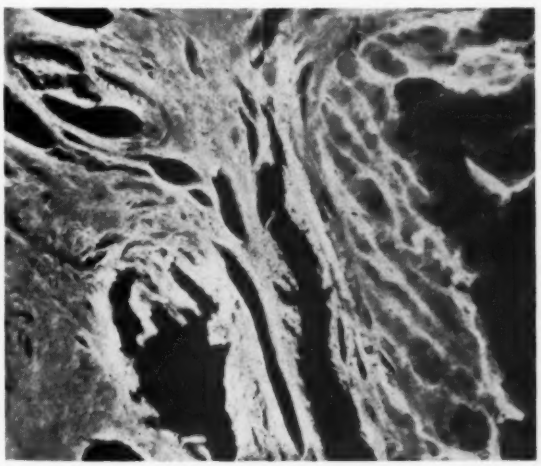


Fig. 12. Historoentgenogram of adenocarcinoma of the rectum. ×90.

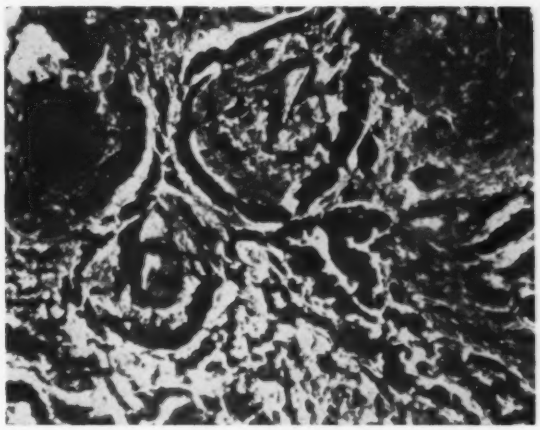


Fig. 13. Historoentgenogram of adenocarcinoma of the ovary. ×90.

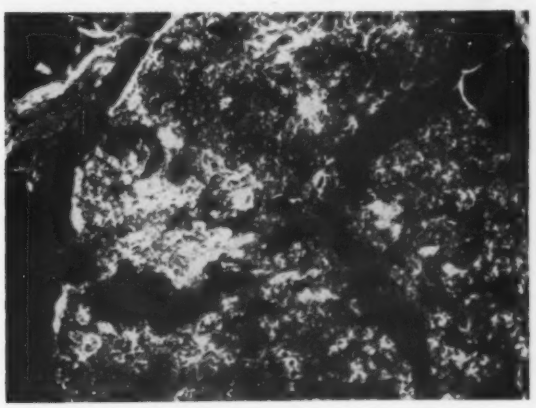


Fig. 14. Historoentgenogram of squamous cell carcinoma in the neck. ×120.

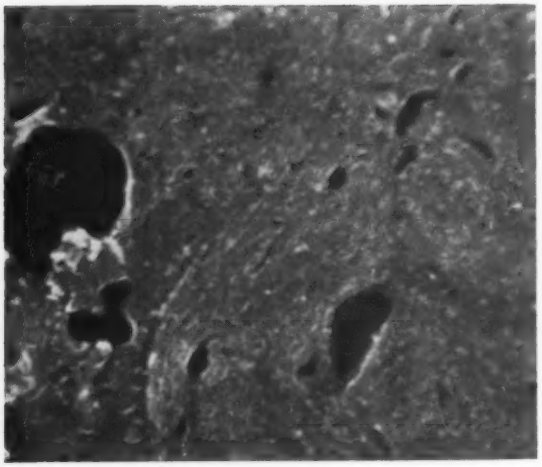


FIG. 15. Historoentgenogram of lymph node. ×90.

What is the cause of this preferential thorotrast adsorption by cancer tissue?

Thorotrast is known to be a solution of colloidal particles possessing a negative electrical charge. The easy and complete mixture of thorotrast in a neutral solution such as blood or any body fluid (secretory or excretory) with a prevailing negative charge is explained as due to the identity of charges. Little is known of the electrical charges possessed by cells and tissues in the body. Maximow and Bloom[6] point out that "the most recent evidence is in favor of the view that it [staining] depends upon the physical processes." The electrical property of cells and tissues is probably a very important factor responsible for the adsorption of contrast media and there are many other unknown factors. It is quite reasonable to suppose that the elective adsorption of thorotrast by some tissue elements (including cancerous tissue) is caused by opposite electrical charges between them. But the final solution of this problem requires special investigation.

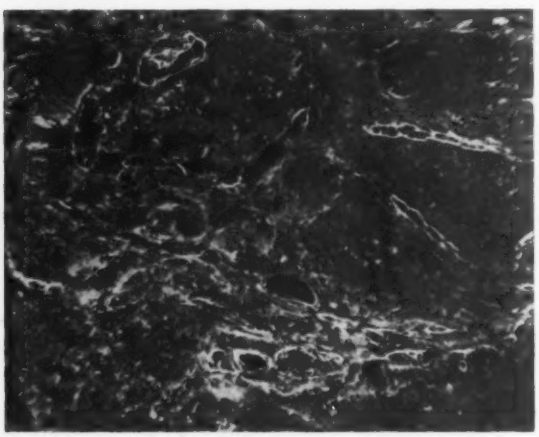


FIG. 16. Historoentgenogram of lymph node. ×90.

In our work we used a low power. But the use of roentgen rays of longer wave length and of emulsions with finer grain will enable us to apply higher power and therefore to improve the roentgen-ray morphological analysis of cells and tissues in the case of cancer.

SUMMARY

1. A new technique of historoentgenography of cancer tissue, by impregnation with thorotrast, is described and recommended.

2. It is proved through historoentgenography that there is a considerable adsorption of thorotrast by cancer tissue, sometimes even a selective adsorption.

3. Thorotrast adsorption by cancer tissue has both practical and theoretical value. In the former, a quick and easy diagnostic technique by means of historoentgenography; in the latter, another step in the study of physical properties of normal and cancer tissues.

Department of Anatomy
University of Ottawa
Ottawa, Canada

The author is greatly indebted to Dr. J. Auer and Dr. D. Magner for their aid in all questions connected with anatomy and pathology and to Dr. A. L. Richard, Dean of the Medical Faculty of the University of Ottawa, for the financial support of this research.

REFERENCES

1. BARCLAY, A. E. Micro-arteriography. *Brit. J. Radiol.*, 1947, *20*, 394–404.
2. BOHATYRTSCHUK, F. Über Ergebnisse der Mikroröntgenographie. *Acta radiol.*, 1944, *25*, 351–365.
3. BOHATYRTSCHUK, F. Totale experimentale Macro- und Mikroröntgenographie. *Fortschr. a. d. Geb. d. Röntgenstrahlen*, 1943, *68*, 159–174.

4. Clark, G. L. Medical, biological and industrial applications of monochromatic radiography and microradiography. *Radiology*, 1947, *49*, 483–495.
5. Lamarque, P. Historadiography. *Brit. J. Radiol.*, 1938, *11*, 425–435.
6. Maximow, A. A., and Bloom, W. A Textbook of Histology. W. B. Saunders Company, Philadelphia, 1948.
7. Mitchell, G. A. G. Microradiographic demonstration of tissues stained by metallic impregnation. *Nature*, London, 1950, *165*, 429–430.
8. Mitchell, G. A. G. Microradiography in biology. *Brit. J. Radiol.*, 1951, *24*, 110–117.

RADIOISOTOPES AS SOURCES OF GAMMA RAYS FOR THERAPY*

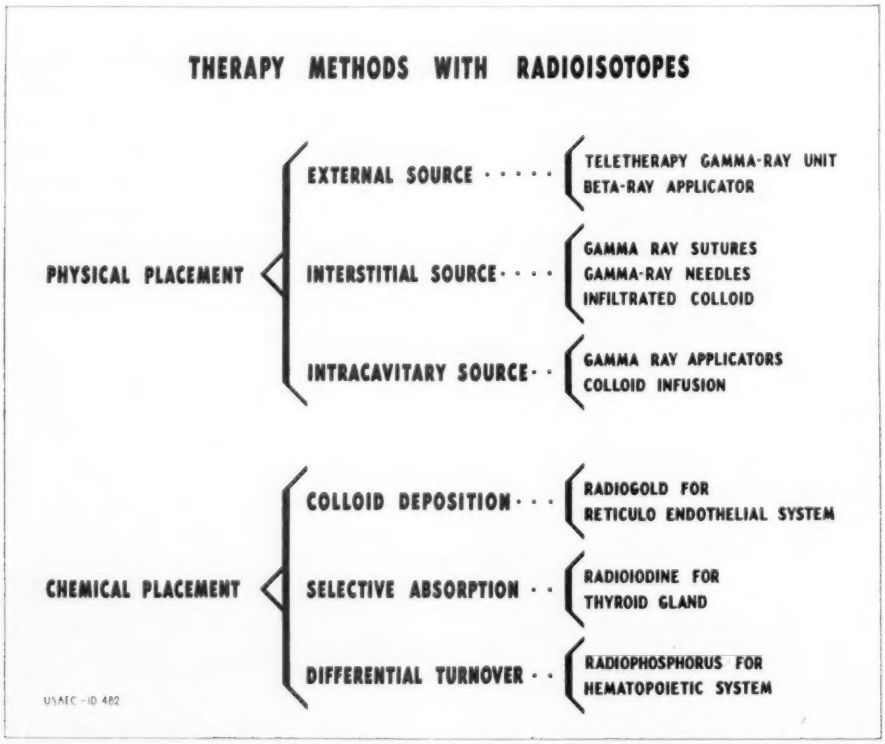
By PAUL C. AEBERSOLD, PH.D.
Director, Isotopes Division, United States Atomic Energy Commission
OAK RIDGE, TENNESSEE

INTRODUCTION

AVAILABILITY of radioisotopes produced with the uranium chain reactor means that the radiologist now has at his disposal many radioactive materials which may prove uniquely useful. The growing importance of reactor-produced materials in the field of radiology is evidenced by the fact that the name of this JOURNAL was changed with the first issue of 1952 to include NUCLEAR MEDICINE. As the editor pointed out, "Recognizing the importance of radiosiotopes and the rapidity with which they have been employed within recent years, not only in diagnostic procedures but also as therapeutic agents, it was thought wise to incorporate in the title of the JOURNAL an additional term which would also connote the JOURNAL's interest in atomic medicine."

The therapeutic use of radiomaterials may be divided into those applications dependent on physical placement of the radioactivity and those dependent on chemical placement (Table 1). Applications of the physical placement type are generally based on the use of gamma radiation whereas the chemical placement type more often utilizes beta radiation. Since this paper is concerned with sources of gamma rays, the discussion will be centered around the availability of reactor-produced iso-

TABLE I



* Presented at the Thirty-fourth Annual Meeting, American Radium Society, Chicago, Ill., June 8–10, 1952.

Table II

USEFUL GAMMA RAY EMITTING ISOTOPES

ISOTOPE	HALF-LIFE	GAMMA RAY ENERGIES-Mev	APPROX. SPEC. ACT.*
HIGH ENERGY (OVER 1 Mev)			
Co 60	5.3 y	1.17, 1.33	20 C/g
Ag 110	270 d	10 γ's: 0.676 TO 1.516 0.885(81%), 1.389(33%)	0.65
Eu 152, 154	13, 16 y	~ 0.3, ~ 1.2	?
Ta 182	117 d	33 γ's: 0.0462 TO 1.237 0.66, 0.885, 0.9 MOST INTENSE	7
MEDIUM ENERGY (0.5 TO 1 Mev)			
**Cs 137	37 y	0.662 (2.6m Ba 137)	20 (Cs_2SO_4, d=3.5)
**Ce 144	275 d	0.13 (abundant)	
Pr 144 (DAUGHTER)	17.5 m	2.2 1.5 } <10% 0.7	100
Ir 192	70 d	12 γ's: 0.137 TO 0.651	115
LOW ENERGY (< 0.5 Mev)			
Se 75	127 d	10 γ's: 0.067 TO 0.405	0.15
Tm 170	127 d	0.084,	?
W 185	73.2 d	0.134	0.2
Hg 203	43.5 d	0.286	0.2

* REACTOR NEUTRON FLUX = $7 \times 10^{12} n/cm^2/sec$
** FISSION PRODUCT

USAEC-ID-119A

topes for use as external, intersititial and intracavitary sources of gamma radiation.

AVAILABILITY

Although man-made radioisotopes have been available from cyclotron production since the early 1930s, the nuclear reactor, developed during World War II, is the only unit which can produce gamma-ray emitters in sufficient supply and low enough cost for general therapeutic use. Further, reactor production is capable of meeting the demands of all qualified investigators.

In screening the 100 available reactor-produced radioisotopes[3] for useful gamma-ray sources, a rather large number of factors must be taken into consideration. The most important of these are (1) mode of production, (2) half-life, and (3) type and energy of radiation. Also, the nature of the proposed use will determine the suitability of the isotope.

A list of some useful gamma-ray isotopes will indicate the relative importance of these factors (Table II). Reactor-produced isotopes cover a gamma-ray energy range up to about 2.8 mev. The number of gamma-ray emitting isotopes which may be useful is quite extensive. The isotopes listed here, however, have been selected because they have comparatively long half-lives and can now be prepared in source strength comparable to or greater than radium. For convenience of classification they have been arbitrarily grouped in high, medium and low energy categories.

Mode of Production. Radioisotopes are produced in the nuclear reactor by two

processes: (1) fission of uranium 235 or other fissionable nuclei, and (2) neutron absorption by nonfissionable nuclei placed in the reactor for the purpose.[1]

Fission-Product Radioisotopes: The fragments resulting from fission of uranium 235 are generally very unstable nuclear species ranging from element 30, zinc, to element 64, gadolinium. On the basis of probability, however, a greater percentage of the fission fragments will range from elements number 38 to 45 and 54 to 61. Each of the fragments formed will approach a stable nuclear state by a series or chain of beta-ray emissions. The intermediate products formed during the chain decay are the source of the fission products.

The effective production of a fission product depends not only on the relative probability of fission resulting in the isotope, but also on the ability of separating it from other fission products, the original uranium, and other transuranic elements present as contaminants.

Only the two fission products, cesium 137 (half-life of 37 years), and cerium 144 (half-life of 275 days) have half-lives greater than six months and appear feasible for therapeutic sources. These are formed in fission yields of 6.0 per cent and 5.3 per cent respectively[19] and may be separated by chemical and physical-chemical means as separate species.[22] (A yield of several per cent is considered desirable for large scale extraction of a particular species.) Although the parent nuclei, cesium 137 and cerium 144, emit only low energy beta rays, they are useful because of the energetic gamma rays emitted by their short-lived radioactive daughters, barium 137 and praseodymium 144.

Recently, considerable attention has been given to the possible use of multi-kilocurie quantities of cesium 137 for teletherapy.[2] Such units however, will not become available in the immediate future. In the first place, research and isotope production reactors such as those at the National Laboratories of the Atomic Energy Commission cannot supply the radioactive material in the quantities required, but plutonium production or large scale power reactors are necessary; secondly, separation equipment, facilities, and techniques will have to be designed and completed for extracting such large amounts of the radiocesium from the uranium, transuranic elements and other fission products. The combination of these two limiting factors will probably delay a satisfactory supply of sources for such units until 1956 or later.

Production by Neutron Absorption: Production of radioisotopes by neutron absorption yields a much wider variety of radioactive elements than can be obtained through fission. Radioisotopes of most elements from hydrogen to plutonium may be made in this way. The neutron absorption process may be further subdivided into two categories: (1) simple neutron capture in which only a gamma-ray photon is emitted and the product is hence an isotope of the target element, and (2) transmutation in which a proton or alpha particle is emitted and the product is hence an isotope of a different element than the target.

Although neutron absorption is a much more versatile production method, it is also much more dependent on the characteristics of the reactor used as the production unit. It is further dependent on the nuclear characteristics of the target material. Neutron flux and reactor volume are perhaps the most important of the reactor characteristics, whereas cross section and isotope abundance are the important properties of the target. Neutron flux is a measure of neutron density within a nuclear reactor. The value of the flux will depend on the region of the reactor in which it is measured, being at a maximum in the center of the reactor and at a minimum at the outer faces.

The *specific activity* of a radioisotope, which is a measure of the ratio of radioactive to stable atoms in an irradiated material, is directly proportional to *neutron flux* and target *cross section*. The specific

activity of a radioisotope produced in a nuclear reactor by neutron irradiation may be expressed by the following formula:

$$S = \frac{1.64\ \sigma F}{A}\ (1 - e^{-0.693t/T})$$

where:

- S is the specific activity in curies/gram of the target element on removal from the reactor
- F is the neutron flux in neutrons per cm.^{2} per second $\times 10^{-11}$
- A is atomic weight of the element
- σ is activation cross section in barns (1 barn $= 10^{-24}$ cm.^{2})
- t is irradiation time
- T is half-life of isotope formed (same units as t)

This formula is applicable for the production of a radioisotope which does not have a neutron absorption cross section comparable to or greater than the target isotope. For example, stable cobalt 59 has a neutron absorption cross section of about 35 barns. The radiosiotope product, cobalt 60, has an insignificant neutron absorption cross section, hence the "burn-up" of cobalt 60 by an (n, gamma) reaction to produce cobalt 61 is of no importance and the above formula can be used without consideration of additional factors. In producing europium 152, 154, however, the situation is quite different. Europium 151 has a neutron absorption cross section of about 9,000 barns whereas the (n, gamma) product, europium 152, has a nearly comparable cross section of 5,500 barns. The situation is even worse in the case of the neutron irradiation of europium 153 to produce europium 154; the first has a cross section of 400 barns whereas the latter has a cross section of 1,500 barns. Because of this anomaly the influence of "burn-up" must be taken into account in determining the specific activity of the desired product.

It is possible, for example, in the graphite reactor at the Oak Ridge National Laboratory to produce cobalt 60 having a specific activity of about 2 curies/gram. This means an irradiation of one half-life (about 5 years) duration at a thermal neutron flux of 5×10^{11} n/cm.^{2} /sec. In the Canadian reactor at Chalk River it is possible in the same irradiation time to produce radiocobalt having a specific activity of about 20 curies/gram since radioisotopes are usually produced in a flux of 7×10^{12} n/cm.^{2}/sec.[20] With a still higher flux which is available in certain regions of this reactor, the specific activity can be further increased to 40 curies/gram. Reactors will eventually be in operation having fluxes of 10^{14} or greater. At such fluxes cobalt 60 may be produced with a specific activity of 200 curies/gram.

A comparison of tungsten 185 and iridium 192 (which have nearly equal half-lives) will show the importance of cross section. The cross section of tungsten 184 is approximately 0.5 barn and the specific activity of the tungsten 185 formed by its irradiation for one half-life at a flux of 7×10^{12} n/cm.^{2}/sec. is 0.2 curie/gram. Iridium 191, however, has a neutron capture cross section of nearly 400 barns and hence for a similar irradiation the specific activity of the iridium 192 formed is 115 curies/gram.

Specific activity may also be dependent on the *isotope abundance* of the target material. Take the case of selenium 75. This isotope is formed by an (n, gamma) reaction on stable selenium 74 which has a natural abundance of only 0.87 per cent. Simultaneous with the production of selenium 75, (n, gamma) reactions take place on five other stable isotopes of selenium all of which are more abundant in the naturally occurring element. Although the cross section of selenium 74 compared to the cross section of the other stable isotopes tends to compensate for the extremely small abundance of selenium 74, the specific activity of selenium 75 is still too low for most therapeutic applications.

Reactor volume becomes important if the quantity of target to be irradiated is large or if the target has a high neutron cross section. The volume must be large enough to accommodate the target material without appreciably reducing the neutron flux.

Half-Life. Within certain limitations the

half-lives of available reactor-produced radioisotopes will not preclude their therapeutic use. For general distribution and use the half-life must be long enough to permit processing, packaging and shipment. Hence, the catalogue of available radioisotopes includes only those whose half-lives are greater than twelve hours.

The nature of the therapeutic use will, of course, determine whether the half-life of a particular isotope is suitable. For example, radiogold 198, which has a half-life of less than three days, is now being developed as an interstitial seed source. For teletherapy units, however, it is doubtful that any radioactive material having a half-life of less than five years would prove feasible unless special arrangements were made for routinely reactivating the sources. On this basis, only cobalt 60, cesium 137, and europium 152, 154 have been seriously considered for teletherapy units.

Type and Energy of Radiation. By selecting different reactor-produced radioisotopes it is possible to obtain a wide range of radiation energies.

Reasonably long-lived (70 days or longer) gamma-ray sources are available with radiation energies ranging from 0.134 mev. to 1.516 mev. Further, depending on the application, it is possible to select radioactive materials with nearly monoenergetic emissions or materials which emit a wide spectrum of energies. For example, cobalt 60 emits essentially monochromatic radiation, two gamma rays of 1.17 and 1.33 mev., whereas tantalum 182 emits thirty-three different gamma rays covering a wide spectrum of energies. Although no reactor-produced radioisotope is a pure gamma-ray emitter, the beta emission may be so weak as to be easily eliminated by absorption. In the case of cobalt 60 again, the beta ray from this isotope is only 0.31 mev. and can be easily shielded out, thus giving an effectively pure gamma-ray emission.

SOURCES FOR SPECIFIC APPLICATIONS

Gamma-Ray Output. The usefulness of a radioisotope as a source of gamma radiation should obviously not be evaluated on the basis of activity alone but rather on gamma-ray output. Gamma-ray output is proportional to the product of radiation energy per disintegration and quantity of radioactivity in the source (number of disintegrations per unit time). In the range of energies from 0.3 to 3.0 mev., a formula for approximating dosage rates for point gamma ray sources is

$$rhm = 0.56\ C\ E$$

where *rhm* is roentgen per hour at a meter, C is the activity of the source in curies and E is the total energy per disintegration of the gamma radiation in mev. A comparison of gamma-ray outputs from various 1 curie sources assuming no self-absorption is shown in Table III.

In actual application, the specific activity of the radioactive material is also important since it affects self-absorption and hence source size. Without going into detail, it is to be noted that gamma-ray output is very dependent on volume, mass and geometry of the source. For example, it has been determined that the output of a large cesium 137 source may be altered by several hundred per cent by simply changing its geometry. The data listed in Table III have not been corrected for self-absorption and hence are maximum values.

Teletherapy Sources. Teletherapy sources will require comparatively large gamma-ray outputs and radioisotopes of high and medium energy range (above 0.5 mev.). Of the high energy gamma-ray emitters (Table II), only cobalt 60 and europium 152, 154 have half-lives long enough to make them practical for this type of source. Within the medium energy range, cesium 137 qualifies for the purpose.

Teletherapy machines may offer several advantages over roentgen-ray machines. They can probably be constructed and maintained more economically; they should yield better skin tolerances and more accurate dosage schedules. Perhaps the biggest possible advantage, however, is com-

TABLE III

COMPARATIVE GAMMA RAY OUTPUT
FROM
ONE CURIE SOURCES*
(ASSUMING NO SELF-ABSORPTION)

ISOTOPE	HALF-LIFE	APPROX. r/hr/1m
Au 198	2.7d	0.22
I-131	8.0d	0.24
Cs 137	37y	0.36
Ta 182	117d	0.61
Ra 226 (0.5mm Pt filter)	1620y	0.84
Co 60	5.2y	1.30

*1 CURIE = 37 BILLION DISINTEGRATIONS/SEC

USAEC-ID-64A

paratively small size and maneuverability. These features are expected to make teletherapy machines more economical and versatile units than comparable energy roentgen-ray machines.

Several teletherapy units have been designed to use cobalt 60,[5,6,7,12,23,24] and sources for three of them have been produced in the high-flux reactor at Chalk River. The Canadian reactor is at present the only reactor available for routine radioisotope production which has a high enough flux to obtain the desirable specific activity of about 20 to 30 curies/gram. Although a number of experimental irradiation and teletherapy units have been made using United States produced cobalt 60 having a specific activity of about 5 curies/gram, the first teletherapy unit using higher specific activity material is scheduled to be put into operation during 1952 by the Medical Division of the Oak Ridge Institute of Nuclear Studies. This unit will use a source of approximately 1,200 curies having a specific activity of approximately 20 curies/gram and a size of 2 by 2 by 1 cm.

Radiocobalt as a teletherapy source has the advantage of nearly monochromatic radiation but the disadvantage of requiring replacement or rejuvenation every few years. From the standpoint of availability, radiocobalt is the best source for the immediate future. High specific activity cobalt 60 is already available in limited supply from Canada. Further, it is expected that a good supply of high specific activity cobalt 60 will become available by 1954 from high flux reactors now being put into operation in the United States.

Recently, the possibility of using longer-lived cesium 137 as a teletherapy source has been studied. Cesium's longer life means that its effective use, before replacement becomes necessary, would be about 7 times longer than in the case of a cobalt 60 source. Another advantage would be that the less energetic gamma-ray emission would permit the use of considerably less shielding. Hence, a telecesium unit would be a much more compact unit than a telecobalt unit.

A serious disadvantage in using cesium 137 for teletherapy as compared to cobalt

Table IV

APPROXIMATE GAMMA RAY OUTPUT AND SOURCE VOLUME
(ASSUMING NO SELF-ABSORPTION)

COBALT 60

CURIES	VOLUME SPEC. ACT. 5C/g	VOLUME SPEC. ACT. 25C/g	r/min./50 cm	r/min/1m
500	11 cm^3	2.2 cm^3	44	11
1000	22	4.4	88	22
1500	33	6.6	132	33

CESIUM 137

CURIES	VOLUME DENSITY ($Cs_2 SO_4$)=3.5	r/min./50 cm	r/min/1m
1000	13.5 cm^3	17	4
5000	67.5	85	21
10000	135	170	42

USAEC-ID65A

60 is that about four times more activity is required for a given gamma-ray output (Table iv).

Also, since cesium 137 is a fission product, the specific activity obtainable has a definite limit which is less than that obtainable with cobalt 60. This means a much larger source volume. It is estimated that a 10,000 curies source, necessary for delivering a dosage of 30 roentgens per minute at a meter, would occupy a volume of approximately 5 cm. diameter by 5 cm. long. With a source of this size, the penumbra problem would of course be appreciably greater than for a cobalt 60 source of comparable gamma-ray output. Still another limitation associated with cesium 137 is that a smaller depth dose is permitted than with cobalt 60. The disadvantage of delayed availability has already been mentioned. In the years to come, however, cesium 137 should find useful applications for gamma-ray therapy.

The combined radioisotopes europium 152, 154 have been considered potentially useful for teletherapy because of their long half-lives, thirteen and sixteen years, and their gamma-ray energies which when filtered would be comparable to that of cobalt 60. There are, however, a number of problems confronting their production. Mention has already been made of the rapid "burn-up" of the two isotopes because of their high neutron absorption cross sections. This means that the neutron efficiency in the production of europium 152, 154 is much less than in the production of cobalt 60; that is, it takes many more neutrons to produce a curie of europium 152, 154 than it does to produce the same quantity of cobalt 60. Also, the gamma-ray output of europium 152, 154 per curie is less than that of cobalt 60. The half-lives of the europium isotopes are, however, approximately three times as long. All factors taken into consideration, the economic feasibility of europium 152, 154 for teletherapy is still questionable. To a large

extent it will depend on production yields which are not now known but which are currently under study.

Interstitial Sources. Major interest in the use of reactor-produced radioisotopes as interstitial sources of radiation has centered around cobalt 60, primarily because its use is so closely allied to the use of radium with which radiologists have wide experience. A number of advantageous physical characteristics led to the early consideration of cobalt 60 for interstitial use.[15,16] One innovation which has made radiocobalt a unique clinical tool is its encasement in thin, flexible, nylon tubing which can be sutured into the tissue to be treated.

Besides the advantages of easy handling with electromagnetic tongs, simple calibration, reasonable cost, and lack of radioactive decay products, radiocobalt has a number of purely clinical advantages.[10] These are: (1) beta radiation can be easily filtered, thus making possible use of thin and inexpensive tubing for encasing the material, (2) the use of multiple weak sources makes possible heavy treatment close to previously irradiated tissue by means of accurate dosage control, and (3) the flexible nylon applicator permits its use in an irregular volume of tumor tissue in a pattern to give a uniform and effective level of radiation to the entire tumor.

This type of source has already been used with success. A typical application is the transfixion of the portions of iliac lymph nodes not removable during a pelvic operation for malignancy, with the active segments of one or more radioactive (radiocobalt-nylon) threads.[13] The filamentous extensions are brought together and held in a hemostat and the incision closed to them from both ends. After an exposure of seven days, the radioactive sources are easily withdrawn through the incision without reopening the abdomen. The same sources have also been used for the treating of nonresectable head and neck cancer.[11]

Most recently, radiogold has been investigated for interstitial use as a radioactive gold 198 wire encased in a nonradioactive thin gold sheath.[17,18] Since radiogold is short lived (half-life of 2.7 days) and since gold is a noble metal, it is possible to leave small sources in the irradiated tissue without subsequent removal. It has the advantage over radon of easier techniques of preparation and handling. Another advantage may arise from the fact that the less energetic gamma rays from gold 198 have a half-thickness in soft tissues only about 60 per cent as great as those from cobalt 60.

It is possible that fixed sources suitable for interstitial purposes could be made using other radioisotopes such as I^{131} and Cs^{137} but no developmental work along this line has been done as yet.

Although radium has been used widely as an interstitial source, it is interesting to speculate what would have happened if radium had been discovered only as an induced isotope. Radium has the one advantage of long half-life, but this is the only advantage. Its radiation characteristics are not as well suited for interstitial therapy as a number of other radioactive materials. Also, because of its physical and chemical characteristics it is not as easy to handle as most other radioactive materials. Similarly, in the case of radon, radiation characteristics are not particularly in its favor for interstitial use. Further, because radon is a gas, the problem of handling is quite complex. Indeed, if radium had been discovered only as an induced isotope, it is questionable whether it would have been selected over all other isotopes for interstitial use.

Intracavitary Sources. The use of reactor-produced gamma-ray emitters as intracavitary sources of radiation has been quite limited. Cobalt 60 has been used by a few groups for the intracavitary treatment of uterine cancer. Others have used cobalt 60 for treatment of cancer of the bladder by introducing a nearly point source through a catheter into a bag which is distended to form a sphere in the bladder.

Some work has been done with beta-ray emitters in animal experimentation on the intracavitary radiation treatment of peptic ulcers and gastric carcinoma. It is possible that studies of this type might be protracted to using weak gamma-ray emitters for clinical applications of similar conditions.

Beta-Ray Therapy. It was pointed out earlier that therapeutic applications of radioisotopes dependent upon physical placement of the activity are generally based on the use of gamma radiation. An exception is the use of radiogold in certain interstitial and intracavitary applications. Radioactive gold 198 in colloidal form has been used as an interstitial source by infiltration or infusion directly into the tissue to be treated.[8,9] When used in surface or subsurface tumors, it has been found that colloidal gold injected into the hard tissue tends to be confined there for the effective life of the activity. Radiogold colloid has also been used for intracavitary treatment by direct injection into the pleural and peritoneal cavities.[14] In such applications it has been found to be particularly effective in reducing pleural effusion and ascites.[4]

Although radiogold emits both beta and gamma radiation, in the applications described here most of the "therapeutic" radiation arises from the beta rays. While the subject of beta-ray therapy is outside the limits of this paper, these uses of radiogold have been mentioned as an interesting exception to the more usual type of physical placement applications.

Diagnostic Use of Gamma Rays. Numerous inquiries have been made about the possibility of using low energy gamma-ray emitters as radiation sources for diagnostic radiography. A number of gamma-ray isotopes have been widely used as diagnostic tools, but all such uses depend on the biochemical tracer characteristics of the radioactive material. Conversely, almost no development has been made for using radioisotopes as fixed sources for diagnosis.

In a recent article it was suggested that it might be possible to use radioactive thulium inside the body as a radiographic source to obtain more satisfactory views from unconventional angles. With standard roentgenographic techniques detail is often obscured by superimposed structures.[21]

An examination, however, of low energy gamma-ray emitters producible in a nuclear reactor (Table 1) indicates that none are now available with half-lives longer than five months and with sufficient source strengths and specific activities to be particularly well suited for this type of application. Although certain possibilities exist for future development, it is doubtful that such a diagnostic use will be widely exploited in the near future.

CONCLUSION

We have briefly surveyed those reactor-produced gamma-ray emitting isotopes which are already useful sources for therapy and some of those which may prove useful in the future. Also, such factors as mode of production, half-life, type and energy of radiation, gamma-ray output, and economies of production have been discussed in terms of availability and application.

Some of the clinical applications discussed herein are only now beginning to be exploited; others are still in the early phases of study and development. Since availability and costs of reactor-produced isotopes are in general not limiting factors in their application, the future use of these materials as therapeutic sources should be limited only by the attention afforded them by radiologists and other medical specialists.

Isotopes Division
U. S. Atomic Energy Commission
Oak Ridge, Tennessee

REFERENCES

1. AEBERSOLD, P. C. Nuclear Reactors: Production of Radioisotopes. In: Medical Physics. Vol. II. Otto Glasser, Editor. Year Book Publishers, Inc., Chicago, 1950.
2. BRUCER, M. Some proposed teletherapy units. *Nucleonics*, 1952, *10*, No. 4, 43–45.
3. Catalog and price list of radioactive and stable

isotopes. Radioisotope Sales Department, Oak Ridge National Laboratory. Carbide and Carbon Chemicals Company, Oak Ridge, Tennessee.

4. Chamberlain, R. H., Klingensmith, P., and Hale, J. Colloidal radioactive gold in the management of recurrent ascites and pleural effusions. Presented before the Thirty-seventh Annual Meeting of the Radiological Society of North America, Chicago, December 6, 1951.
5. Dixon, W. R., Garrett, C., and Morrison, A. Room protection measurements for cobalt^{60} teletherapy units. *J. Canad. A. Radiologists*, 1952, *3*, 11–15. (Abstr. this Journal, March, 1953, *69*, 530.)
6. Green, D. T., and Errington, R. F. Considerations in design of cobalt^{60} beam therapy equipment. *J. Canad. A. Radiologists*, 1952, *3*, 20–24. (Abstr. this Journal, March, 1953, *69*, 531.)
7. Grimmett, L. G., Kerman, H. D., Brucer, M., Fletcher, G. H., and Richardson, J. E. Design and construction of multicurie cobalt teletherapy unit. *Radiology*, 1952, *59*, 19–31.
8. Hahn, P. F., Goodell, J. P. B., Sheppard, C. W., Cannon, R. O., and Francis, H. C. Direct infiltration of radioactive isotopes as means of delivering ionizing radiation to discrete tissues. *J. Lab. & Clin. Med.*, 1947, *32*, 1442–1453.
9. Hahn, P. F., and Carothers, E. L. Use of radioactive colloidal metallic gold in treatment of malignancies. *Nucleonics*, 1950, *6*, No. 1, 54–62.
10. James, A. G., Williams, R. D., and Morton, J. L. Radioactive cobalt as an adjunct to cancer surgery. *Surgery*, 1951, *30*, 95–105.
11. James, A. G., Williams, R. D., and Morton, J. L. Use of radioactive cobalt in nonresectable head and neck cancer. *Cancer*, 1951, *4*, 1333–1336.
12. Johns, H. E. Physical characteristics of radiation in cobalt^{60} beam therapy. *J. Canad. A. Radiologists*, 1952, *3*, 2–6. (Abstr. this Journal, March, 1953, *69*, 529–530.)
13. Morton, J. L., Callendine, G. W., Jr., and Myers, W. G. Flexible thread source of 1.25 million-volt gamma rays for therapy. *Cancer Research*, 1951, *11*, 270–271.
14. Muller, J. H. Personal communication.
15. Myers, W. G. Radioactive needles containing cobalt^{60}. *Science*, 1948, *107*, 621.
16. Myers, W. G. Applications of artificially radioactive isotopes in therapy. I. Cobalt^{60}. Am. J. Roentgenol. & Rad. Therapy, 1948, *60*, 8 6–823.
17. Myers, W. G., and Colmery, B. H., Jr. Radioactive Au^{198} in gold seeds for cancer therapy. *Cancer Research*, 1952, *12*, 285–286.
18. Myers, W. G., Colmery, B. H., Jr., and McLellon, W. M. Radioactive gold-198 for gamma radiation therapy. Am. J. Roentgenol., Rad. Therapy & Nuclear Med. To be published.
19. Nuclei formed in fission: decay characteristics, fission yields, and chain relationships. *J. Am. Chem. Soc.*, 1946, *68*, 2411–2442.
20. Radioelements and accessories. Eldorado Mining & Refining (1944) Limited. (Available from Commercial Products Division, Atomic Energy of Canada, Limited, P.O. Box 93, Ottawa, Canada.)
21. Radiography with radioactive isotopes. Editorial. *J.A.M.A.*, 1952, *148*, 1508.
22. Rupp, A. F. Problems in manufacture of fission-product therapy sources. *Nucleonics*, 1952, *10*, No. 4, 45–46.
23. Smith, I. H. Cobalt^{60} team therapy: some influences and advantages. *J. Canad. A. Radiologists*, 1952, *3*, 16–19. (Abstr. this Journal, March, 1953, *69*, 530–531.)
24. Watson, T. A. Clinical possibilities of cobalt^{60} beam unit. *J. Canad. A. Radiologists*, 1952, *3*, 7–10. (Abstr. This Journal, March, 1953, *69*, 530.

ROENTGEN-RAY MOTION PICTURES BY MEANS OF SCREEN INTENSIFICATION*†

By RUSSELL H. MORGAN, M.D., *and* RALPH E. STURM
BALTIMORE, MARYLAND

THE production of roentgen-ray motion pictures or cinefluorograms is one of the most difficult technical problems facing the experimental radiologist. In spite of a great deal of work by many investigators, the quality of such films is characteristically poor and the radiation exposure needed to produce them is dangerously high.

Although it may not seem so superficially, the problems of roentgenographic quality and radiation exposure in cinefluorography are closely interrelated. This will become apparent when it is pointed out that when any roentgenographic procedure, including cinefluorography, is performed, all of the diagnostic information which is recorded during the examination is carried to the film by the roentgen-ray photons which pass through the patient. When the number of photons is large, the amount of diagnostic information delivered to the film is relatively high. Conversely, when the number of photons is small, the quantity of information delivered to the film is low. Since radiation exposure is proportional to the number of photons involved in the roentgenologic process and since roentgenographic quality is essentially a direct function of the amount of diagnostic information recorded by the film, roentgenographic quality bears a close and fundamental relationship to radiation exposure.

An example of how we make use of this principle from day to day in general roentgenography may be found in our methods of exposing films with conventional intensifying screens. When films of relatively great detail are desired, so-called "definition" screens which require a long exposure are employed; on the other hand, so-called "speed" screens which require a relatively small exposure are used when less detail is satisfactory.

From the foregoing, it may appear that the chances of obtaining cinefluorographic films of better quality than those which have been produced heretofore are relatively poor since the amount of radiation necessary to produce such films is close to the maximum limit which may be tolerated by the patient and by the roentgen-ray equipment. This, however, is not necessarily true. Although a roentgen-ray beam, after it passes through a structure, contains a definite amount of diagnostic information, governed by the number of photons present in the beam, the roentgenographic process may not be able to record all of this information. That is, in a roentgenographic examination the characteristics (photon density) of the roentgen beam transmitted by the patient determine the ultimate limit of detail which can be recorded by any roentgenographic material; however, the detail recorded by a particular material may be considerably less than this maximum if its fidelity of reproduction is poor. If such should be the case in cinefluorography, an improvement in the quality of roentgen-ray motion pictures may be achieved by improvements in cinefluorographic apparatus without the use of additional roentgenographic exposure. Indeed, if present-day cinefluorographic equipment is very inefficient, we might ultimately expect to obtain satisfactory motion pictures with even less exposure than that now employed.

With the foregoing in mind, let us examine for a moment how well the cinefluorographic process makes use of the available

* From the Department of Radiology, The Johns Hopkins Medical Institutions. Presented at the Fifty-second Annual Meeting, American Roentgen Ray Society, Washington, D. C., Sept. 25–28, 1951.
† The work described in this paper was supported in part with a grant from the National Cancer Institute of the National Institutes of Health, Washington, D. C.

detail contained within the roentgen-ray beam as it emerges from a patient under examination.

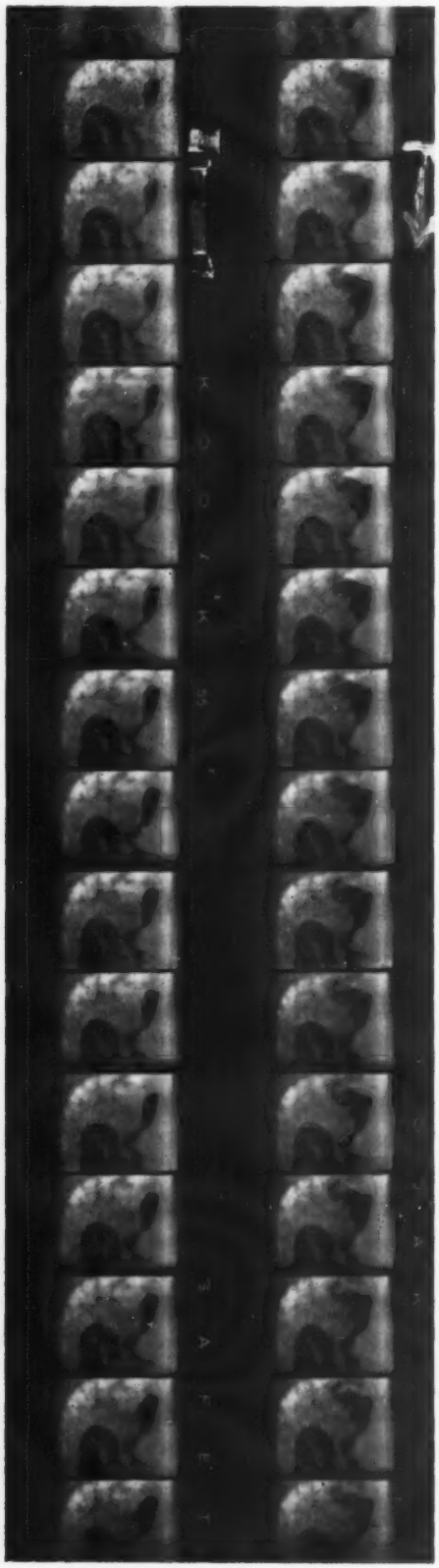
A great deal of cinefluorographic work has been performed with equipment which includes a conventional fluoroscopic screen of the zinc sulfide type (*e.g.*, Patterson Type B-2), a lens of a large aperture (f/0.9 to f/1.5) and high-speed 16 mm. motion picture film (*e.g.*, Eastman Super XX). Calculations of the efficiency of this equipment, based upon fluctuation theory,[2] indicate that the detail of its films, measured in terms of photographic resolution, is only approximately 8 per cent of the inherent detail contained within the roentgen-ray beam as it falls upon the fluoroscopic screen. It is evident from this that much can be accomplished by a more effective use of the radiant energy delivered to the cinefluorographic unit. Some improvement may be obtained by increasing the size of the film. If one uses 35 mm. rather than 16 mm. film, the detail rises to approximately 14 per cent of that contained within the roentgen-ray beam. Such an improvement is a step in the right direction. but hardly approaches the ultimate limit which is desired. If one goes a step further and employs 70 mm. film, further gains may be realized; however, even here the detail of the cinefluorograms is only 20 per cent of the inherent detail of the roentgen beam.

One can of course go to the use of full-sized roentgenographic film as Ruggles did in his roentgen cinematograph many years ago. This method is inviting because calculations and experiment indicate that this technique records essentially all of the detail included in the roentgen-ray beam. However, the cost of full-sized film and its associated equipment is high. Further, the film is extremely difficult to move at the frame speeds demanded by motion picture procedures. It appears that to increase the size of the film is not a satisfactory solution to the problem of cinefluorographic detail.

One may now ask what are the possibilities of improving the screen, the lens and/or the film used in present-day cinefluorographic equipment. As far as the screen is concerned, it appears that this unit is already relatively efficient and that little improvement may be anticipated in this direction. The situation concerning the lens also is not too hopeful. Within our present range of thinking, it does not appear likely that gains in resolution of more than two times are likely for some time to to come. As far as the film is concerned, it is well known that all photographic materials are relatively inefficient. However, the problem of producing more efficient film has been continuously under investigation in many research laboratories for many years and it does not appear that much may be expected from this direction.

The foregoing facts are certainly discouraging to those who have been working in the field of cinefluorography. However, the outlook need be discouraging only as long as one limits his thinking to methods which employ only the conventional fluoroscopic screen, lens and film. If one deviates from this traditional viewpoint, the outlook becomes considerably brighter. Indeed if one applies screen intensification methods to cinefluorography many of the problems which have appeared insurmountable heretofore seem amenable to solution.

The employment of a screen intensification system which brightens fluorescent images by several thousand times makes possible the use of photographic lenses of high resolution and films of fine grain. Under these circumstances, if the screen intensifier is able to record all of the detail inherently included in the roentgen-ray beam, the ultimate in cinefluorographic detail will be achieved, even with 16 mm. film. Furthermore, the increase in light made available by the intensification process permits one to make roentgen-ray motion pictures with considerably less radiation exposure than is otherwise possible. Of course, it should be pointed out that when one reduces the exposure under these circumstances, one sacrifices detail in ac-



cordance with the principles previously outlined. However, there are many instances where one may be willing to sacrifice some detail in order to obtain motion pictures of greater length than have been possible heretofore or to obtain motion pictures with reduced radiation to the patient.

For the past few months, we have been investigating the usefulness of the screen intensifier which we have developed at the Johns Hopkins Hospital[1] in the field of cinefluorography. This screen intensifier at the present time does not reach the ultimate limit of registering all of the detail which is contained within the roentgen-ray beam projected upon it; calculations indicate that it records only one-third of this detail. The motion pictures which we have been able to obtain with the unit therefore may be improved by a factor of about three times. Since research in screen intensification methods has only just begun, it is reasonable to believe that this improvement will eventually be achieved.

Although our screen intensifier, in its present stage of development, does not constitute the ideal solution to cinefluorographic problems, we have been able to produce several full-length motion pictures of a number of roentgenoscopic examinations. A typical example of one of these is the barium enema film, a portion of which is illustrated in Figure 1. This film was made on a child seven years of age, with the roentgen-ray generator operating at 90

←

Fig. 1. Strip of 16 mm. film taken from a roentgen-ray motion picture of a barium enema, photographed by screen intensification methods. The patient was a seven year old child whose abdomen measured 10 cm. in thickness. The roentgen-ray generator operated at 95 kv. (peak) and 5 ma.; the tube-screen distance was 27 inches. The total radiation exposure to which the patient was subjected was 20 roentgens, an extremely low value compared to conventional practice. It is anticipated that improvements in screen intensification systems may ultimately make possible cinefluorograms which have a resolution approaching three times greater than that exhibited by the film when similar exposure conditions are used.

kv. (peak) and 5 ma. The tube-screen distance was 27 inches, the lens aperture was f/2.0 and the film was Eastman Super X. The examination required almost three minutes to film. The total radiation delivered to the patient in this interval was approximately 20 roentgens. Although the detail recorded in this film does not compare with that of conventional roentgenograms, it is reasonably good in view of the very small exposure employed. Improved detail could have been gained by an increase in the roentgen-ray exposure but this did not seem desirable because of the protracted length of the film. It should also be remembered that no film image whatsoever would have been obtained with conventional cinefluorographic techniques using even the fastest films and lenses under similar exposure conditions.

The performance of the screen intensifier so far indicates that screen intensification is likely to do much to advance the cause of cinefluorography. Already, it is possible to make protracted motion pictures with greatly reduced radiation exposure to the patient; furthermore, there is every reason to expect that before long motion pictures which contain all of the detail which is inherently included in the roentgen-ray beam will be feasible. We can therefore turn toward the production of roentgen-ray motion pictures which will be of aid in teaching and in many experimental procedures where the investigations are either drawn out or prohibit an excessive amount of radiation.

Russell H. Morgan, M.D.
Johns Hopkins Hospital
Baltimore 5, Maryland

REFERENCES

1. Morgan, R. H., and Sturm, R. E. Johns Hopkins fluoroscopic screen intensifier. *Radiology*. In press.
2. Sturm, R. E., and Morgan, R. H. Screen intensification systems and their limitations. Am. J. Roentgenol. & Rad. Therapy, 1949, *62*, 617–634.

DISCUSSION

Dr. Paul C. Hodges, Chicago, Ill. Image amplification has passed the most serious danger of infancy and has begun a slow but healthy period of maturation. The danger that is past lay in an excessive enthusiasm that anticipated the rapid perfection of the basic idea until it had reached a stage of routine clinical usefulness. Such enthusiasm is notoriously fickle and is apt to dissolve into disillusionment if clinical results fail to come promptly.

Dr. Morgan and Dr. Sturm, I am sure, are not planning to hurry back to Baltimore, tear out all their conventional fluoroscopes and replace them with electronic amplifiers, but they have shown us that real progress has been made in a well planned and well executed program of research. It is gratifying that our Society has recognized the excellence of their work by bestowing upon them its Gold Medal, and it is to be hoped that other agencies will continue and enlarge the substantial monetary grants that work of this sort requires.

Eventually, image amplification will reach a commercial stage and become self-supporting, but that time is not yet here. For the present, progress depends upon research workers like Morgan and Sturm, supplied by government grants or an occasional unusually enlightened commercial manufacturer who is willing to continue to expend developmental funds in an area that cannot be expected to bring immediate financial returns. All radiologists are indebted to such investigators and to the agencies that support them.

Dr. Robert R. Newell, San Francisco, Calif. I have a question. It looked to me as though the contrast amplification was very good there, that one could see the contrast between the lumbar spine and the surroundings very well, but that the outlines were not so sharp as one would like. I wonder if that lack of sharpness is attributable to difficulties in the early part of the instrumentation, or if it is due to the coarseness of the television scanning. If the latter, could one have some kind of an arrangement to turn on at will, by which only a small portion of the image would be scanned, and so reduce the grain, or what might be as good, lengthen the time of integration for each element of image and so reduce the statistical fluctuation?

Dr. Morgan (closing). Dr. Newell's points

are very well taken. They epitomize the situation, I think, very well.

As far as the detail is concerned, the detail at the present time is limited by the television type of system we are using. The possibility of going to smaller fields for things in which one is particularly interested happens to be one of the methods which we are now pursuing, and which we anticipate will produce good results. In addition to that, I think it is necessary to use other than conventional image orthicon tubes for pickup of the very low light levels used in fluoroscopy. Research is now progressing toward the development of more sensitive tubes.

I think that a combination of what you say, Dr. Newell, plus more sensitive pickup tubes, will for a given fluoroscopic level of radiation energy improve the detail or sharpness by a factor of about three times. If one wants further improvements for particular teaching material or for particular experimental work, one can go up in roentgen-ray beam intensity, too. After all. the beam intensities used in the work we have presented here are pretty low and for short sequences there is no need for restricting oneself to such low levels as we have done. We have deliberately, in the production of this film, used low levels just to see what the limit is, so to speak. However, we know that the detail will go up practically as the square root of the roentgen-ray beam intensity; so that if you increase the milliamperage from 5 to 20 milliamperes, you will increase your detail by a factor of 2. When one does make motion pictures with our present apparatus that is exactly what happens.

And so for short sequences where radiation dosage is not too much of a factor, one can improve the detail that way. Of course, there are health physicists who would be a little concerned with going to the higher dosages, but I think for certain restricted work higher dosage rates are all right. So, a combination of these various things—different field sizes, more sensitive tubes, and increasing radiation exposure for short sequences—will, I think, produce eventually pretty good cinefluorograms.

Vol. 70, No. 1

MULTIFILM CASSETTE FOR USE IN LAMINAGRAPHY*

By WALDRON M. SENNOTT, M.D., *and* HOWARD E. WORRELL, *Chief Technician*
STATEN ISLAND, NEW YORK

THE theory and technique of simultaneous tomography (laminagraphy) were described by de Abreu[1] in November, 1948. This reference stimulated us to construct an improved multifilm cassette, using air as a spacer.

Simultaneous laminagraphy enables one to perform a laminagraphic series of the chest in approximately one-third of the time required by the standard method. The amount of radiation to the patient for a given series is greatly reduced, and inconvenience to the patient is correspondingly minimized. Furthermore, the patient's position at time of exposure is exactly the same for each roentgenogram of the series.

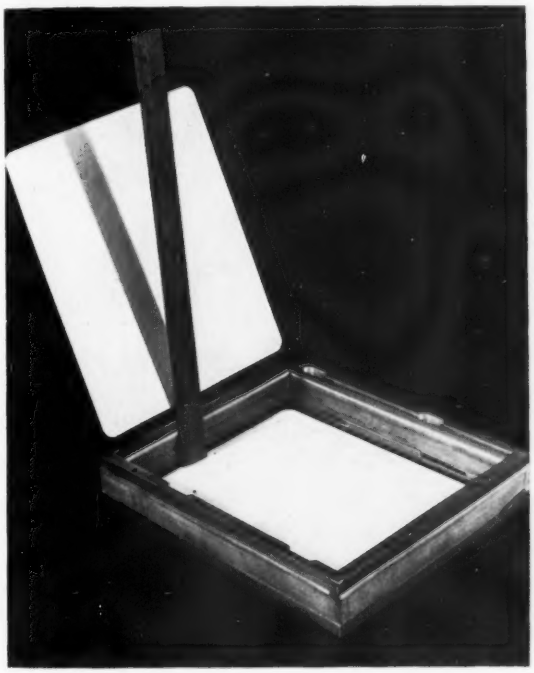


FIG. 1. Dismantled cassette attached to a box lined with lead.

To construct this model, a standard cassette was dismantled and reassembled with a lead-lined box frame of appropriate size (Fig. 1). Four air-containing film spacers, each of which was 1 cm. thick, were constructed by stretching air tight rubber dam over balsa wood frames 10 inches long and 12 inches wide. A small ball-valve was inserted into an inside corner of each air spacer to provide for air refills. Front intensifying screens of varying speeds were then cemented to opposing spacer surfaces as well as to the inside of the top and bottom of the cassette box (Fig. 2). These spacers proved superior to those made of blotting paper, balsa wood, and other solid materials in two respects. First, the use of air instead of a solid decreased absorption of radiation considerably. Second, the inflatable air spacers provided a positive pressure film-screen contact.

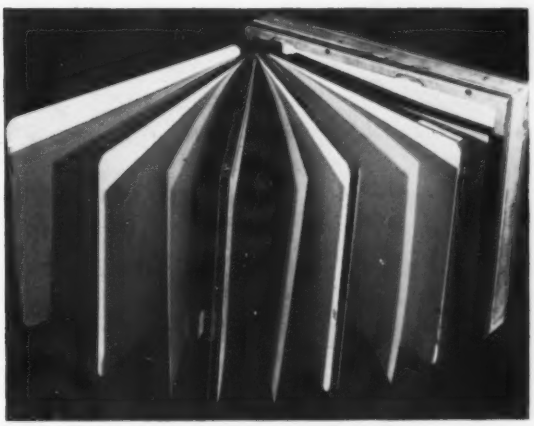


FIG. 2. View of air-containing rubber dam spacers to which screens are attached. Films are interspersed.

Although the differences in the amounts of radiation reaching the five films were not negligible, differences in developing times compensated sufficiently for the variation over a 4 cm. range for which the cassette was constructed, although, beyond this thickness, influences of the inverse square law and the composition of the

* From the Department of Radiology, U. S. Marine Hospital, Staten Island, New York; operated by the U. S. Public Health Service, Federal Security Agency.

FIG. 3. Cassette loaded.

films and intensifying screens imposed practical limitations. Various methods are being experimented with to increase uniformity of film exposure.

The multifilm cassette was easily adapted to an existing roentgenographic table of standard make without need for removing the Potter-Bucky diaphragm. The apron of the table next to the tube stand was easily altered to allow for ready access to the attachment area beneath the table. Photographs of the cassette fully loaded and closed are presented (Fig. 3 and 4).

FIG. 4. Cassette loaded and closed.

Thus far, the cassette has been used for chest examinations, particularly to study lesions in and adjacent to the mediastinum. An illustration is included (Fig. 5).

SUMMARY

The description of an improved multifilm cassette for use in laminagraphy is presented.

It is helpful in considerably reducing the time, the amount of radiation, and inconvenience to the patient usually involved in the production of a series of laminagrams.

Waldron M. Sennott, M.D.
U. S. Marine Hospital
Staten Island 4, New York

REFERENCE

1. DE ABREU, M. Theory and technique of simultaneous tomography. AM. J. ROENTGENOL. & RAD. THERAPY, 1948, *60*, 668–674.

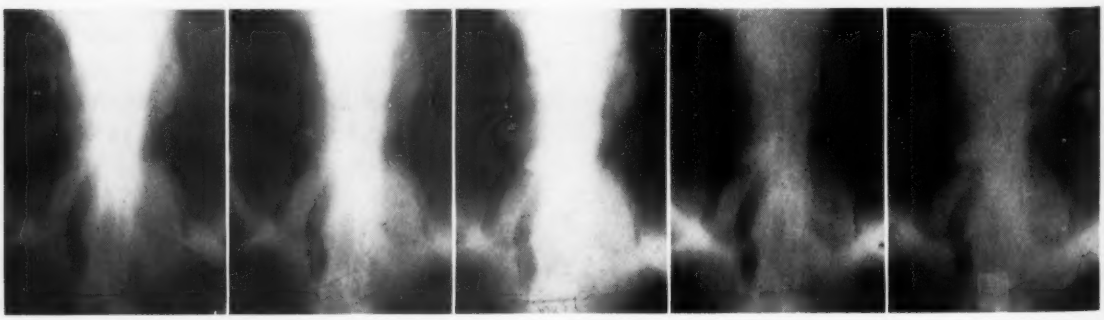


FIG. 5. Series of roentgenograms at 1 cm. intervals produced by one exposure. Large substernal mass.

VOL. 70, NO. 1

INTERCHANGEABLE MASK AND COMPRESSION CONES FOR MUCOSAL RELIEF

By MORIS HORWITZ, M.D., *and* SIDNEY D. MESIROW, M.D.
BEVERLY HILLS, CALIFORNIA

FREQUENTLY, during the course of roentgenoscopic examination of the gastrointestinal tract in which spot films are exposed, the roentgenoscopist may desire the use of a spot larger than ordinarily readily obtainable with presently available spot film compression apparatus. Thus, it is frequently desirable to obtain a roentgenogram of the entire barium-filled stomach, a large segment of small intestine, or a flexure of the colon—all with or without the use of compression for mucosal relief. While some manufacturers do make interchangeable masks having various sized openings, none are available, to our knowledge, of a single easily handled apparatus employing two sizes of openings and compression cones.

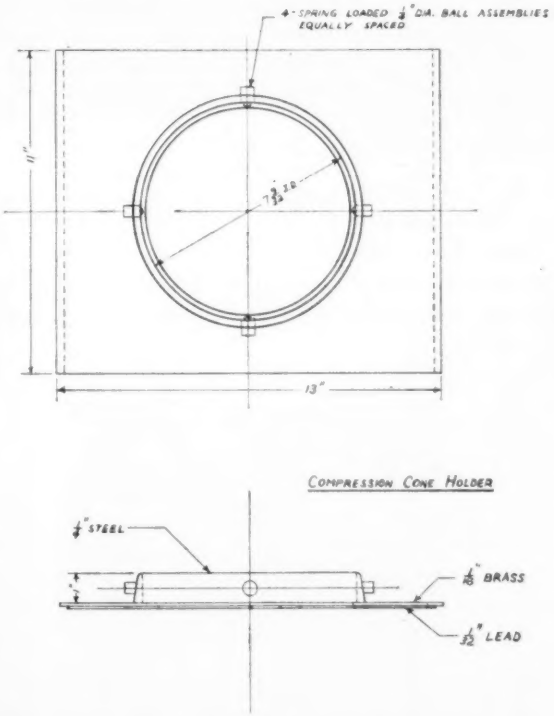


FIG. 1. Compression cone holder. Chrome all over, except aluminum cones and lead.

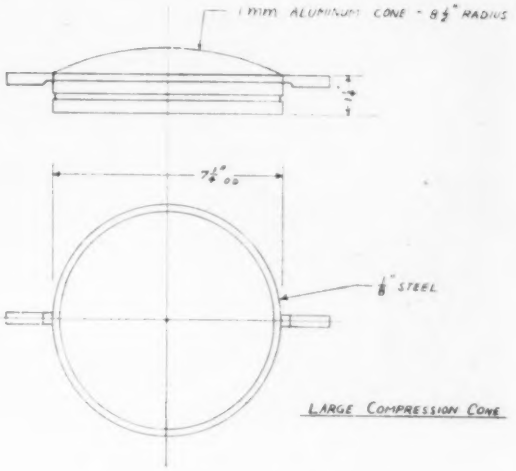


FIG. 2. Large compression cone.

It is essential that the equipment be easily and quickly interchangeable in the darkness of the roentgenoscopic room, since the size of the exposed area may necessarily be frequently changed during the course of a single roentgenoscopic examination, as, for example, the obtaining of mucosal relief roentgenograms of the entire stomach followed by small roentgenograms of a smaller segment of the stomach or of the duodenal bulb.

We employ a spot film device using 8 by

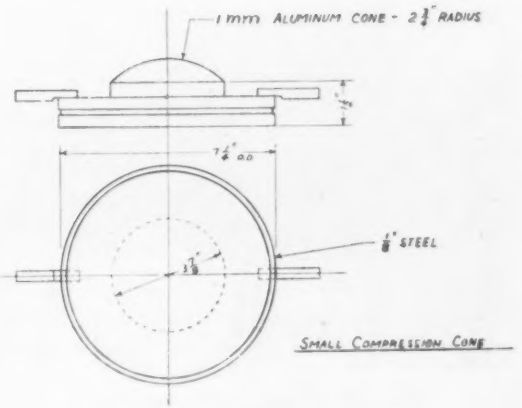


FIG. 3. Small compression cone.

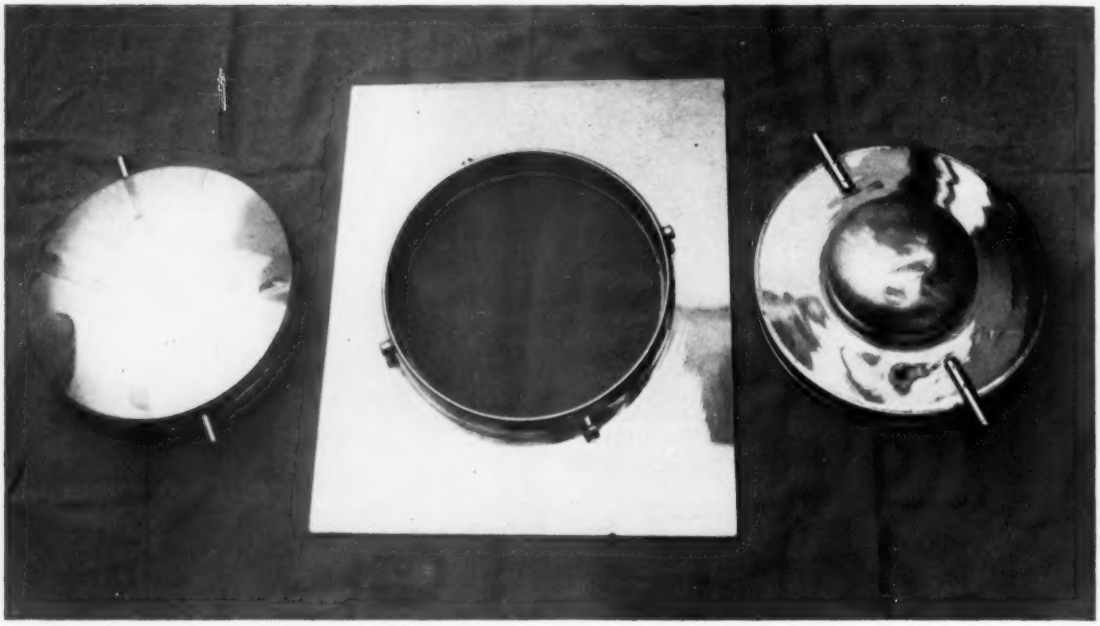


FIG. 4. Photograph cone holder and cones.

10 inch films which may be exposed in single frames, double frames, or the film may be exposed in a sequence of four exposures. We felt that the employment of a small spot ($2\frac{3}{4}$ inches) on a single 8 by 10 film was wasteful as well as frequently not projecting the entire area desired, and we have designed a device which may be used with or without interchangeable compression cones for use with our equipment. We believe that this accessory may be readily adapted to most types of equipment presently in operation. In these days of threatened film rationing the conservation of film will also be an important factor. The basic materials are fairly easy to obtain and the cost of fabrication negligible, especially when the factor of film saving is also a consideration.

FIG. 5. Photograph cone holder and larger cone in operation.

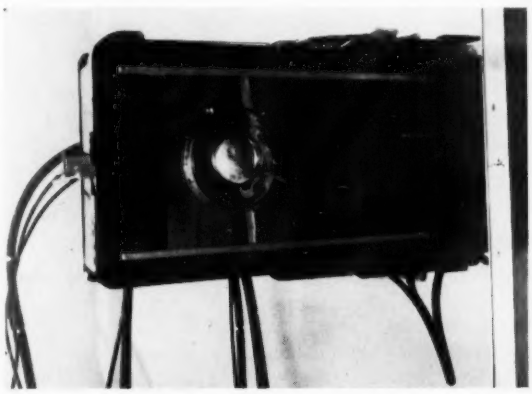


FIG. 6. Photograph cone holder and small cone in operation.

During that part of the roentgenoscopic examination in which neither the masking diaphragm nor the spot device is used, the apparatus may be shoved to one side of

the central roentgenoscopic area by sliding it along a pair of light weight aluminum tracks securely fastened to the back of the roentgenoscopic screen frame. During use, the apparatus is centered to the screen by sliding it medially, the exact center having been found and marked with a ball-bearing spring clip which fits into an appropriate groove notched on one edge of the masking device.

The authors are indebted to Mr. W. B. Johnson, Mr. L. Blaisdell, and Mr. Karl Burkholder of the Los Angeles X-Ray Division of the Westinghouse Electric Corporation for many suggestions and for fabrication of the actual apparatus.

441 North Camden Drive
Beverly Hills, California

ISODOSE INDICATOR*

By JOHN S. LAUGHLIN,† PH.D., *and* WALTER J. HENDERSON, B.S.

THIS note describes a treatment planning device which aids in determining the contribution of any roentgen-ray field to any desired plane in a body, particularly when the axis of the beam is not in the given plane. Though this device was developed for use with our medical betatron, it can be used for any roentgen-ray beam whose isodose surfaces have been flattened by differential filtration.

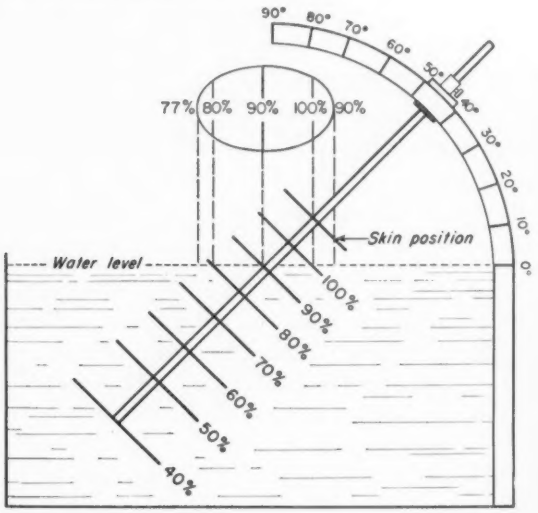


FIG. 1. Side view. The rod has been adjusted so that its angle with respect to the water surface and the distance from the skin position to the surface are the same as those of the actual roentgen-ray beam with respect to a plane in the body.

Usually most of the fields employed in any case have their axes in the same plane. The resultant dose distribution is ordinarily determined in several ways including the following two:

(1) Thin transparent sheets with the isodose contours of the roentgen-ray field inscribed on them are superimposed and their dose levels added visually. This is usually done in several steps until all fields employed in that plane have been added.

(2) Films whose density varies such that their transmission is proportional to the dose distribution of a given field are superimposed. Each field used in the plane is represented by a film. The superimposed films are placed on a uniform light source and a new film is exposed to the transmitted light. The density distribution on the exposed film is the same as the dose distribution that will be produced by these fields. Such master films are readily made with the betatron since the density of certain films varies linearly with the dose at high energies.[1,2]

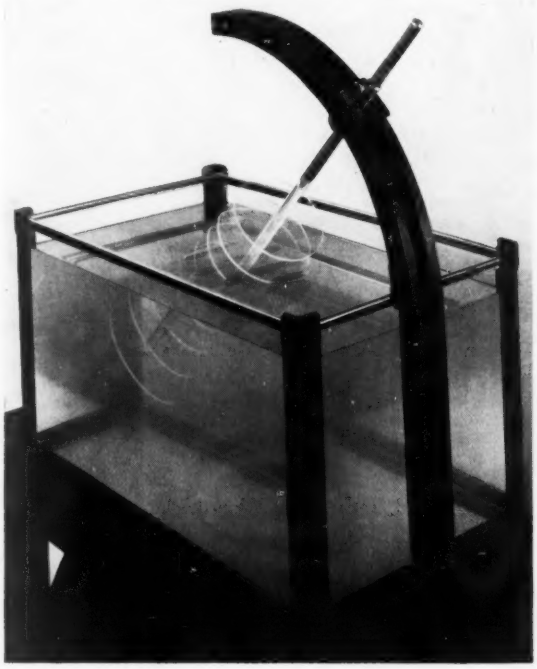


FIG. 2. Oblique view of isodose indicator with a rod for a circular field in use.

However, these procedures do not give the dose distribution in any given plane contributed by fields whose axes are not in the particular plane. The dose contribution in such a case is readily visualized and measured with the device shown in Figures 1 and 2. Its simplicity depends on the use of fields with flat isodose surfaces.

* From the Department of Radiology, College of Medicine, University of Illinois, Chicago, Illinois.
† Present address: Department of Physics, Memorial Center, New York 21, New York.

The surface of the liquid is the particular plane in which it is desired to know the contribution of a field whose axis is not in this plane. The rod represents the axis of the beam and can be adjusted to intersect the plane of the water surface at any angle and at any depth along the rod. Consequently, the orientation of the rod with respect to the water surface is the same as the orientation of the axis of the roentgen-ray beam with respect to the plane in question. A series of discs are mounted on the rod and represent the location and size of the isodose surfaces of a circular field. Rectangular sheets on another rod represent a rectangular field. The intersection of these discs (or rectangles) with the liquid surface gives the location and dimensions of the isodose surfaces in that plane. The length and separation of these intersections are measured with a small ruler. A typical dose configuration thus obtained is shown projected above the intersections in Figure 1. The dose contributions of circular fields have elliptical boundaries while those of rectangular beams are bounded by trapezoids. This dose contribution, as shown projected in Figure 1, is then added directly to the contributions of other fields to obtain the net dose distribution.

Department of Physics
Memorial Hospital
444 East 68th St.
New York 21, New York

REFERENCES

1. Laughlin, J. S., and Davies, W. D. Procedure in dose distribution measurement of 25 mev. x-rays. *Science*, 1950, *111*, 514-516.
2. Laughlin, J. S., Beattie, J. W., Lindsay, J. E., and Harvey, R. A. Dose distribution measurements with University of Illinois 25 mev. medical betraton. Am. J. Roentgenol. & Rad. Therapy, 1951, *65*, 787–799.

THE AMERICAN JOURNAL OF ROENTGENOLOGY, RADIUM THERAPY AND NUCLEAR MEDICINE

Editor: LAWRENCE REYNOLDS, M.D. *Assistant Editor:* RUTH BIGELOW, B.S.

Associate Editors: HARRY HAUSER, M.D., TRAIAN LEUCUTIA, M.D., RUSSELL H. MORGAN, M.D., EDWARD B. D. NEUHAUSER, M.D., WENDELL G. SCOTT, M.D.

Consulting Editorial Board: See front cover.

Published by: CHARLES C THOMAS, PUBLISHER, 301–327 East Lawrence Avenue, Springfield, Illinois.

Issued monthly. Annual subscription: United States, Mexico, Cuba, Central and South America, $15.00; Canada, $16.00; other countries, $17.00. Current single numbers, $1.50. Advertising rates submitted on application. Editorial office, 110 Professional Building, Detroit 1, Michigan. Office of publication, 301–327 East Lawrence Avenue, Springfield, Illinois. Information of interest to authors and readers will be found on page iv.

Officers and Standing Committees

AMERICAN ROENTGEN RAY SOCIETY

President: Charles L. Martin, Dallas, Texas; *President-Elect:* Harry M. Weber, Rochester, Minn.; *1st Vice-President:* Fred O. Coe, Washington, D C.; *2nd Vice-President:* Lester W. Paul, Madison, Wis.; *Secretary:* Barton R. Young, Germantown Hospital, Philadelphia 44, Pa.; *Treasurer:* Wendell G. Scott, 35 North Central, Clayton 5, Mo.

Executive Council: C. L. Martin, H. M. Weber, F. O. Coe, L. W. Paul, B. R. Young, W. G. Scott, Lawrence Reynolds, R. J. Reeves, R. H. Morgan, W A. Evans, Jr., H. D. Kerr, B. P. Widmann, W. E. Chamberlain, P. C. Hodges, Clyde A. Stevenson, Chairman, Scott and White Clinic, Temple, Texas.

Program Committee: B. R. Young, Philadelphia, Pa., R. J. Reeves, Durham, N. C., Lawrence Reynolds, Detroit, Mich., W. A. Evans, Jr., Detroit, Mich., C. A. Stevenson, Temple, Texas, Harry M. Weber, Chairman, Mayo Clinic, Rochester, Minn.

Publication Committee: J. C. Bell, Louisville, Ky., M. K. Geyman, Santa Barbara, Calif., R. J. Reeves, Chairman, Durham, N. C.

Finance Committee: E. L. Jenkinson, Chicago, Ill., R. K. Arbuckle, Oakland, Calif., R. H. Morgan, Chairman, Baltimore, Md.

Committee on Scientific Exhibits: C. A. Good, Rochester, Minn., E. B. D. Neuhauser, Boston, Mass., W. A. Evans, Jr., Chairman, Detroit, Mich.

Representatives on American Board of Radiology: B. R. Kirklin, Rochester, Minn., H. Dabney Kerr, Iowa City, Iowa, U. V. Portmann, Tucson, Ariz.

Representative on National Research Council: A. O. Hampton, Washington, D. C.

Editor: Lawrence Reynolds, 110 Professional Building, Detroit 1, Mich.

Assistant Editor: Ruth Bigelow, 110 Professional Building, Detroit 1, Mich.

Fifty-fourth Annual Meeting: Netherland Plaza Hotel, Cincinnati, Ohio, September 29–October 2, 1953.

AMERICAN RADIUM SOCIETY

President: Edith H. Quimby, New York, N. Y.; *President-Elect:* John E. Wirth, Pasadena, Calif.; *1st Vice-President:* H. Dabney Kerr, Iowa City, Iowa; *2nd Vice-President:* Grant H. Beckstrand, Long Beach, Calif.; *Secretary:* Robert E. Fricke, Mayo Clinic, Rochester, Minn.; *Treasurer:* Douglas J. Roberts, 85 Jefferson St., Hartford 6, Conn.

Executive Committee: Leland R. Cowan, Chairman, Salt Lake City, Utah, Hugh F. Hare, Los Angeles, Calif., Howard B. Hunt, Omaha, Nebr.

Program Committee: Edith H. Quimby, Chairman, New York, N. Y., Richard H. Chamberlain, Philadelphia, Pa., Vincent P. Collins, Houston, Texas, Herbert M. Parker, Richland, Wash., John E. Wirth, Pasadena, Calif.

Publication Committee: Harry Hauser, Chairman, Cleveland, Ohio, J. Samuel Binkley, Oklahoma City, Okla., Peter A. Nelson, Chicago, Ill.

Public Relations Committee: John A. Wall, Chairman, Houston, Texas, E. C. Baker, Youngstown, Ohio, Robert L. Brown, Emory University, Ga.

Janeway Lecture Committee: Douglas Quick, Chairman, New York, N. Y., Gioacchino Failla, New York, N. Y., Frederick W. O'Brien, Boston, Mass.

Representatives on the American Board of Radiology: Douglas Quick, New York, N. Y., B. P. Widmann, Philadelphia, Pa., Frederick W. O'Brien, Boston, Mass.

Committee on Arrangements: A. N. Arneson, Chairman, St. Louis, Mo., Franklin L. Payne, Philadelphia, Pa., Jesshill Love, Louisville, Ky., Edith H. Quimby, New York, N. Y.

Representatives on National Committee for Radiation Protection: Edith H. Quimby, New York, N. Y., Theodore P. Eberhard, Philadelphia, Pa.

Thirty-sixth Annual Meeting: The Homestead, Hot Springs, Virginia, March 14, 15 and 16, 1954.

EDITORIALS

PSEUDO-EPIPHYSES IN HAND AND FOOT

EVERY radiologist is familiar with the appearance of supernumerary centers of ossification at that end of a metacarpal or metatarsal which is normally without an independent bony epiphysis, *i.e.*, the distal end of the first metacarpal or metatarsal and the proximal ends of the second to the fifth. The term "pseudo-epiphysis" is commonly applied to these centers, but is better reserved for those epiphyses that show a bony bridge connecting them with the shaft. On the other hand, the truly independent centers in the same location should be designated as supernumerary epiphyses. The term "pseudo-epiphysis" was first introduced by Welcker in 1884, although Uffelmann in 1863 had already given a detailed description of the accessory epiphysis in the head of the first metacarpal.

The epiphyseal arrangement of the first metacarpal and metatarsal, displaying a secondary center at the base and not at the head as the other metacarpals and metatarsals, is identical with that of the phalanges and has therefore been offered as an additional argument in favor of the thumb lacking a true metacarpal. But the frequent occurrence of a pseudoepiphysis or supernumerary epiphysis at the distal end of the first metacarpal weakens this argument considerably. Modern anatomists generally do not uphold the interpretation of the phalangeal nature of this bone.

On the basis of histological evidence, Hasselwander ascribes to the ossification process in the head of the first metacarpal an intermediate position between that of the epiphyses with, and those without a separate bony center. According to Uffelmann and Hasselwander the pseudo-epiphysis is formed by an extension of the ossification process into the cartilaginous extremity of the metacarpal. In its earliest stage a rod of osteogenic tissue invades the epiphyseal cartilage. Later the distal end of this ossifying rod enlarges and assumes mushroom shape, until only a narrow cleft separates it from the metaphysis. Pseudo-epiphyses at the proximal end of the other metacarpals have a similar appearance. Rochlin and more recently Weinert have classified the different forms of pseudo-epiphyses on the basis of the width of the stalk that joins the accessory epiphyseal center to the metaphysis. Brailsford believes it possible that the connecting bridge of a pseudo-epiphysis may be projected in such a way as to be invisible on the film. Thus it may simulate a true supernumerary epiphysis.

According to Weinert, pseudo-epiphysis formation is most common at the distal end of the first metacarpal, with the proximal ends of the second, fifth, third and fourth following in this order of frequency. If transitional forms with only small indentations at the extremity of the metacarpals are included, then the order of frequency changes to metacarpals II, V, I, III, IV. Rarely do pseudo-epiphyses occur at the distal ends of the basal and middle phalanges, but they are quite common in metatarsal I.

Although the theory of the origin of the pseudo-epiphyses, as given here, is most commonly accepted, it should not be overlooked that such experienced observers as Schinz and Siegert before him, offer quite a different explanation. They assume that a pseudo-epiphysis arises as an originally independent bony center within the cartilaginous epiphysis and that the bony bridge or stalk is an expression of secondary fusion with the metaphysis. Thus the dis-

tinction between supernumerary and pseudo-epiphyses would be irrelevant and the two phenomena would differ only in the time of fusion with the shaft.

Weinert, in his recent publication, has given us data on the time of appearance and fusion of the pseudo-epiphyses. Surprisingly he found them quite often in infants under one and a half years of age, *i.e.*, long before the appearance of the normal epiphyseal centers in the metacarpals, occasionally as early as the first month after birth. Except for the pseudo-epiphysis on metacarpal 1, they usually fuse with the metaphysis long before puberty. The pseudo-epiphysis on the first metacarpal appears later than the others, approximately at the same time as the normal epiphyses, and fuses late during puberty. True supernumerary epiphyses may also appear and fuse earlier than normal epiphyses (Brailsford), although in rare cases they may persist for a long time beyond the date of fusion of the normal epiphyses, occasionally even throughout life. The same may be true for pseudo-epiphyses. Posener, Walker and Weddell checked the progress of pseudo-epiphyses during the eighteen month period and found that some of them became more, others less marked and a third group disappeared completely.

Hasselwander has given the most plausible explanation for the occurrence of pseudo-epiphyses. Normally there is a balance between cartilaginous proliferation and ossification in the epiphyseal region. If in a circumscribed portion of the epiphyseal disc ossification prevails over cartilaginous proliferation, the ossification process will invade the cartilaginous epiphysis in this limited area, and a pseudo-epiphysis results. Such irregularities of ossification are particularly apt to occur where both—osteogenesis and cartilaginous proliferation—are inhibited for some reason.

As physicians we are, of course, interested in the clinical significance of pseudo-epiphysis formation. The question has been approached on a statistical basis by Stettner, who found that pseudo-epiphyses are twice as common in congenitally stigmatized chlidren as in normal children past eighteen months of age. Weinert encountered the anomaly in more than one metacarpal, sometimes in all five, in the following disease groups: (1) congenital cerebral lesions, (2) generalized malformations, (3) endocrine disturbances, particularly myxedema and adiposogenital dystrophy, (4) underdevelopment due to malnutrition and avitaminosis, and in other intercurrent diseases such as infections, and (5) leukemias. True supernumerary epiphyses occur under the same conditions, yet much more rarely. Rochlin and other continental authors likewise regard the affection as being of clinical significance, particularly when present in several centers of hand or foot.

Pseudo-epiphysis formation seems to be a sensitive indicator of a disturbance of ossification, somewhat comparable in clinical significance with the transverse growth lines. While harmless and consistent with a normal state of health, if occurring in a single bone, multiple appearance should stimulate our interest in the clinical cause of the condition.

Ernest Lachman, M.D.
Department of Anatomy
University of Oklahoma
School of Medicine
Oklahoma City 4, Oklahoma

REFERENCES

1. Welcker, H. Die morphologische Bedeutung des ersten Daumengliedes. Halle, 1884.
2. Uffelmann, J. Der Mittelhandknochen des Daumens, seine Entwicklungsgeschichte und Bedeutung. Goettingen, 1863.
3. Hasselwander, A. Bewegungssystem. In: Peter, K., Wetzel, G., and Heiderich, F. Handbuch der Anatomie des Kindes, Vol. 2. J. F. Bergmann, Munich, 1938, pp. 403–589.
4. Rochlin, D. G. Ueber die Pseudoepiphysen und deren Bedeutung in der Endokrinologie. *Ztschr. f. d. ges. Anat.* (Abt. 1), 1927, *82*, 354–367.
5. Weinert, P. Ein Beitrag zur Frage der Pseudoepiphysen. *Anat. Anz.*, 1952, *99*, 1–20.
6. Brailsford, J. F. The Radiology of Bones and Joints. Fourth edition. Williams & Wilkins Company, Baltimore, 1948.
7. Schinz, H. R., Baensch, W. E., Friedl, E., and Uehlinger, E. Lehrbuch der Röntgendiag-

nostik. Vol. I. Fifth edition. Georg Thieme, Stuttgart, 1950.

8. Siegert, F. Die Osteogenesis chondrodysplastica mit besonderer Berücksichtigung des Pseudoepiphysen-Problems. *Fortschr. a d. Geb. d. Röntgenstrahlen*, 1933, *48*, 666–682.

9. Posener, K., Walker, E., and Weddell, G. Radiographic studies of metacarpal and metatarsal bones in children. *J. Anat.*, 1939, *74*, 76–79.

10. Stettner, E. Ossificationsstudien am Handskelet; über Pseudoepiphysen des Handskelets. *Ztschr. f. Kinderh.*, 1931, *51*, 459–472.

RALPH DAVIS LEONARD
1886-1952

DR. RALPH DAVIS LEONARD, for many years a member of the American Roentgen Ray Society, died at the Melrose Hospital at Melrose, Massachusetts, on May 27, 1952, of cardiac failure.

Dr. Leonard was born in Westfield, Massachusetts, August 6, 1886, the son of Rev. Joel M. Leonard and Mary Mason Leonard. He graduated from Boston Latin School, received his A.B. degree from Harvard College in 1907 and his M.D. degree from Harvard Medical School in 1910. After serving a medical internship at the Boston City Hospital, he was appointed assistant physician at that institution where he spent two years with Dr. Francis

H. Williams and Dr. Samuel Ellsworth. In 1914, he married Florence E. Sinclair who, with his daughter, Mrs. Wilfred L. (Ruth) Freyberger, survives him. In the same year he became associated with Dr. Arial W. George in the private practice of radiology in Boston. During the ensuing years he served as roentgenologist at the Malden Hospital, the Melrose Hospital, the Cambridge Hospital and the Brooks Hospital in Brookline and as an instructor in roentgenology at Tufts Medical School. He was a diplomate of the American Board of Radiology and a fellow of the American College of Radiology. Until his retirement he was an active member of the American Roentgen Ray Society and had served on its executive council. He was chairman of the old Eastern Section of the Society and initiated and planned the first Conference of Eastern Radiologists which was held in Boston in 1926. He was a member and former president of the New England Roentgen Ray Society and he had served as chairman of the Section of Radiology of the Massachusetts Medical Society.

With his fine educational background and his training in medical diagnosis, Dr. Leonard was an ideal consultant. Because of his careful logical reasoning, his opinions were sought not only by the physicians of the community, but also by his fellow radiologists. He was especially interested in the roentgen diagnosis of lesions of the chest, gastrointestinal tract and gallbladder and, in the days before the use of the gallbladder contrast media, he became particularly skillful in diagnosing gallbladder disease from indirect evidence. He contributed a number of papers to the journals and collaborated with his associate, Dr. George, in the publication of three books: "Roentgen Diagnosis of Surgical Lesions of the Gastro-intestinal Tract," "The Gall Bladder," and "The Vertebrae."

Although he carried the load of a very busy private practice, Dr. Leonard found time to devote to the community affairs of the city of Melrose where he made his home. He served twelve years on the school committee and was chairman for a number of years, he was president of the Y.M.C.A. and held an interest in the local newspaper. After he retired from active practice in 1945, he became vice president and later president of the Melrose Savings Bank and acting superintendent and later chairman of the executive committee of the Melrose Hospital. Under his leadership the hospital was modernized and equipped. Through his efforts a new surgical wing was added which will stand as a memorial to his lifelong devotion to the hospital.

Charles W. Blackett, M.D.

JAMES MILLAR BONNAR
1878-1952

DR. JAMES MILLAR BONNAR, aged seventy-four, for twenty-eight years radiologist at St. Luke's Hospital up to his retirement at the age of sixty in October, 1939, died at his home in Middleboro, Massachusetts, following a heart attack on November 27, 1952.

Born in Glasgow, Scotland, October 22, 1878, he was the son of Thomas J. and Jane M. Bonnar. The family came to New Bedford, Massachusetts, in 1887 following the death of his father. Dr. Bonnar attended schools here, graduating from high school in the class of 1896. He was graduated from Bellevue Medical College in New York in 1901, and in 1903 began the prac-

tice of medicine in New Bedford. He was elected a physician to the Overseers of the Poor in 1906. Dr. Bonnar was one of the pioneers in radiology in New Bedford and became head of this department at St. Luke's Hospital, New Bedford, in 1911.

Dr. Bonnar was a diplomate of the American Board of Radiology, a member of the American Roentgen Ray Society and the American College of Radiology. During World War II he was a member of the New Bedford Draft Boards. He was a member of the New Bedford Paskamansett Masonic Lodge, transferring to the Masonic Lodge in Fairmont, and later to Mayflower Lodge in Middleboro. He was past chief of Caledonian Lodge of this city and past patron of Chapter 49 of the Order of the Eastern Star of this city. His church affiliation while in New Bedford was with the North Congregational Church. At the time of his death he was an officer of the Central Congregational Church in Middleboro. He was president of the New Bedford High School Alumni Association in 1932.

Dr. Bonnar married Miss Jane L. Forsythe in 1908. Besides his wife, he is survived by three sons and two daughters.

Dr. Bonnar left New Bedford, Massachusetts, in 1940 to become head of the Department of Roentgenology at Fairmont Hospital, in West Virginia, retiring in 1949, when he went to Middleboro to make his home.

Max Ritvo, M.D.

SOCIETY PROCEEDINGS, CORRESPONDENCE AND NEWS ITEMS

MEETINGS OF ROENTGEN SOCIETIES*

UNITED STATES OF AMERICA

AMERICAN ROENTGEN RAY SOCIETY
Secretary, Dr. Barton R. Young, Germantown Hospital, Philadelphia 44, Pa. Annual meeting: Netherland Plaza Hotel, Cincinnati, Ohio, Sept. 29–Oct. 2, 1953.

AMERICAN RADIUM SOCIETY
Secretary, Dr. R. E. Fricke, Mayo Clinic, Rochester, Minn. Annual meeting: The Homestead, Hot Springs, Virginia, March 14–16, 1954.

RADIOLOGICAL SOCIETY OF NORTH AMERICA
Secretary, Dr. D. S. Childs, 713 E. Genesee St., Syracuse 2, N. Y. Annual meeting: Palmer House, Chicago, Ill., Dec. 13–18, 1953.

AMERICAN COLLEGE OF RADIOLOGY
Executive Secretary, William C. Stronach, 20 N. Wacker Drive, Chicago 6, Illinois.

SECTION ON RADIOLOGY, AMERICAN MEDICAL ASSOCIATION
Secretary, Dr. T. Leucutia, Harper Hospital, Detroit 1, Mich. Annual meeting: New York, New York, June 1–5, 1953.

FIFTH INTER-AMERICAN CONGRESS OF RADIOLOGY
General Secretary, Dr. Eugene P. Pendergrass, 3400 Spruce St., Philadelphia 4, Pa. Meeting at Shoreham Hotel, Washington, D. C., April 24–30, 1955.

ALABAMA RADIOLOGICAL SOCIETY
Secretary, Dr. J. A. Meadows, Jr., Medical Arts Bldg., Birmingham 5, Ala. Meets time and place Alabama State Medical Association.

ARIZONA RADIOLOGICAL SOCIETY
Secretary, Dr. R. Lee Foster, 15 E. Monroe, Phoenix, Ariz. Two regular meetings a year. The annual meeting at time and place of State Medical Association and interim meeting six months later.

ARKANSAS RADIOLOGICAL SOCIETY
Secretary, Dr. Fred Hames, 511 National Bldg., Pine Bluff, Ark. Meets every three months and also at time and place of State Medical Association.

ATLANTA RADIOLOGICAL SOCIETY
Secretary, Dr. Albert A. Rayle, Jr., 478 Peachtree St., N.E., Atlanta, Ga. Meets monthly, except during three summer months, on second Friday evening.

BROOKLYN ROENTGEN RAY SOCIETY
Secretary, Dr. J. J. Daversa, 345 75th St., Brooklyn, N. Y. Meets monthly fourth Tuesday, October through April.

BUFFALO RADIOLOGICAL SOCIETY
Secretary, Dr. Mario C. Gian, 610 Niagara St., Buffalo, N. Y. Meets second Monday evening each month, October to May inclusive.

CENTRAL NEW YORK ROENTGEN RAY SOCIETY
Secretary, Dr. Dwight V. Needham, 608 E. Genesee St., Syracuse N. Y. Meets January, May, November.

CENTRAL OHIO RADIOLOGICAL SOCIETY
Secretary, Dr. F. A. Riebel, 15 West Goodale St., Columbus, Ohio. Meets at 6:30 P.M. on second Thursday of October, December, February, April, and June at Columbus Athletic Club, Columbus, Ohio.

CHICAGO ROENTGEN SOCIETY
Secretary, Dr. Elbert K. Lewis, 6337 S. Harvard Ave., Chicago, Ill. Meets second Thursday of each month, October to April inclusive at the University Club.

CLEVELAND RADIOLOGICAL SOCIETY
Secretary, Dr. Mortimer Lubert, 10515 Carnegie Ave., Cleveland 6, Ohio. Meetings at 6:45 P.M. on fourth Monday of each month from October to April.

COLORADO RADIOLOGICAL SOCIETY
President, Dr. W. P. Stampfli, St. Luke's Hospital, Denver, Colo. Meets third Friday of each month at University of Colorado Medical Center or at Denver Athletic Club.

CONNECTICUT VALLEY RADIOLOGIC SOCIETY
Secretary, Dr. E. W. Godfrey, 1676 Boulevard, West Hartford, Conn. Meets second Friday October and April.

DALLAS-FORT WORTH ROENTGEN STUDY CLUB
Secretary, Dr. X. R. Hyde, Medical Arts Bldg., Fort Worth, Texas. Meets in Dallas on odd months and in Fort Worth on even months, on third Monday, 7:30 P.M.

DETROIT ROENTGEN RAY AND RADIUM SOCIETY
Secretary, Dr. J. C. Cook, Harper Hospital, Detroit, Mich. Meets monthly first Thursday, October to May, at Wayne County Medical Society Building.

EAST BAY ROENTGEN SOCIETY
Secretary, Dr. Dan Tucker, 434 30th St., Oakland 9, Calif. Meets first Thursday each month at Peralta Hospital, Oakland.

FLORIDA RADIOLOGICAL SOCIETY
Secretary, Dr. A. Judson Graves, 2002 Park St., Jacksonville, Fla. Meets twice annually, in the spring with the annual State Society meeting, and in the fall.

GEORGIA RADIOLOGICAL SOCIETY
Secretary, Dr. Robert M. Tankesley, 218 Doctors Bldg., Atlanta, Ga. Meets in mid-winter and at annual meeting of Medical Association of Georgia in the spring.

GREATER MIAMI RADIOLOGICAL SOCIETY
Secretary, Dr. E. H. Bryson, 273 Alhambra Circle, Coral Gables, Fla. Meets third Wednesday of each month at Veterans Administration Building.

HOUSTON RADIOLOGICAL SOCIETY
Secretary, Dr. Harry Fishbein, 324 Medical Arts Bldg., Houston 2, Texas. Meets fourth Monday each month at Hermann Hospital.

IDAHO STATE RADIOLOGICAL SOCIETY
Secretary, Dr. Alfred M. Stone, St. Lukes Hospital, Boise, Idaho. Meets annually at same time as Idaho State Medical Association.

ILLINOIS RADIOLOGICAL SOCIETY
Secretary, Dr. Stephen L. Casper, 1101 Maine St., Quincy, Ill. Meets three times a year.

INDIANA ROENTGEN SOCIETY
Secretary, Dr. William M. Loehr, 712 Hume-Mansur Bldg., Indianapolis 4. Meets second Sunday in May.

IOWA RADIOLOGICAL SOCIETY
Secretary, Dr. James T. McMillan, 1104 Bankers Trust Bldg., Des Moines, Iowa. Luncheon and business meeting during annual session of Iowa State Medical Society. The scientific section is held in the autumn.

KANSAS RADIOLOGICAL SOCIETY
Secretary, Dr. Willis L. Beeler, M.D., 700 Kansas Ave., Topeka, Kansas. Meets in spring with State Medical Society, and in winter on call.

KENTUCKY RADIOLOGICAL SOCIETY
Secretary, Dr. E. L. Pirkey, Louisville General Hospital, Louisville 2, Ky. Meets monthly on second Friday at Seelbach Hotel, Louisville.

KINGS COUNTY RADIOLOGICAL SOCIETY
Secretary, Dr. Marcus Wiener, 1430 48th St., Brooklyn, N. Y. Meets Kings County Med. Soc. Bldg. monthly on fourth Thursday, October to May, 8:45 P.M.

LOS ANGELES RADIOLOGICAL SOCIETY
Secretary, Dr. Joseph F. Linsman, 436 N. Roxbury Dr., Beverly Hills, Calif. Meets second Wednesday each month at Los Angeles County Medical Association Building, Los Angeles.

* Secretaries of societies are requested to send timely information promptly to the Editor.

Louisiana Radiological Society
Secretary, Dr. J. R. Anderson, 1130 Louisiana Ave., Shreveport. Meets annually during Louisiana State Medical Society Meeting.

Maine Radiological Society
Secretary, Dr. Hugh Allan Smith, Eastern Maine General Hospital, Bangor, Maine. Meets in early spring, June and fall.

Miami Valley Radiological Society
Secretary, Dr. G. A. Nicoll, 134 Apple St., Dayton, Ohio. Meets second Friday of fall and winter months.

Mid-Hudson Radiological Society
Secretary, Dr. J. W. Walton, Horton Memorial Hospital, Middletown, N. Y. Meets 8:30 P.M., fourth Tuesday each month, September to May.

Milwaukee Roentgen Ray Society
Secretary, Dr. T. J. Pfeffer, 839 N. Marshall St., Milwaukee 2, Wis. Meets monthly on second Monday at University Club.

Minnesota Radiological Society
Secretary, Dr. John R. Hodgson, Mayo Clinic, Rochester, Minn. Meets three times annually, once at time of State Med. Assn., and in spring and fall.

Mississippi Radiological Society
Secretary, Dr. John W. Evans, 117 N. President St., Jackson, Miss. Meets third Thursday of each month at the Rotisserie Restaurant at 6:30 P.M.

Montana Radiological Society
Secretary, Dr. Grant P. Raitt, Suite 413 Medical Arts Bldg., Billings, Montana. Will meet at least once a year.

Nassau Radiological Society
Secretary, Dr. Joseph J. La Vine, 259 North Grand Ave., Baldwin, N. Y. Meets second Tuesday of the month in February, April, June, October and December.

Nebraska Radiological Society
Secretary, Dr. J. F. Kelly, Jr., 816 Medical Arts Bldg., Omaha, Nebr. Meets third Wednesday of each month at 6 P.M. in Omaha or Lincoln.

New England Roentgen Ray Society
Secretary, Dr. Stanley M. Wyman, Massachusetts General Hospital, Boston, Mass. Meets monthly on third Friday, Harvard Club.

New Hampshire Roentgen Ray Society
Secretary, Dr. A. C. Johnston, Elliott Community Hospital, Keene, N. H. Meets four to six times yearly.

New York Roentgen Society
Secretary, Dr. J. R. Freid, 1049 Park Ave., New York 28, N. Y. Meets monthly on third Monday, New York Academy of Medicine, at 8:30 P.M.

North Carolina Radiological Society
Secretary, Dr. J. E. Hemphill, 1420 E. Fifth St., Charlotte 4, N. C. Meets in May and October.

North Dakota Radiological Society
Secretary, Dr. C. O. Heilman, 807 Broadway, Fargo. Meetings by announcement.

Northeastern New York Radiological Society
Secretary, Dr. John F. Roach, Albany Hospital, Albany, N. Y. Meets in Albany area on second Wednesdays of October, November, March and April. Annual meeting will be held in May or June, 1953.

Northern California Radiological Society
Secretary, Dr. Richard C. Ripple, 1215 28th Street, Sacramento, Calif. Meets at dinner last Monday of September, November, January, March and May.

Ohio State Radiological Society
Secretary, Dr. Willis S. Peck, 1838 Parkwood Ave., Toledo 2, Ohio.

Oklahoma State Radiological Society
Secretary, Dr. John R. Danstrom, Medical Arts Bldg., Oklahoma City, Okla. Three regular meetings annually.

Oregon Radiological Society
Secretary, Dr. J. Richard Raines, 214 Medical-Dental Bldg., Portland 5, Oregon. Meets monthly from October to June on the second Wednesday of each month at 8:00 P.M. at the University Club.

Orleans Parish Radiological Society
Secretary, Dr. Joseph V. Schlosser, Charity Hospital, New Orleans 13, La. Meets first Tuesday of each month.

Pacific Northwest Radiological Society
Secretary, Dr. S. J. Hawley, 1320 Madison St., Seattle 4, Wash. Meets annually in May.

Pacific Roentgen Society
Secretary, Dr. L. H. Garland, 450 Sutter St., San Francisco, Calif. Meets annually, during meeting of California Medical Association.

Pennsylvania Radiological Society
Secretary, Dr. J. M. Converse 416 Pine St., Williamsport. Annual meeting, Necho Allen Hotel, Pottsville, Pa., May 22 and 23, 1953.

Philadelphia Roentgen Ray Society
Secretary, Dr. George P. Keefer, American Oncologic Hospital, Philadelphia 4, Pa. Meets first Thursday of each month, at 5 P.M., from October to May in Thompson Hall, College of Physicians.

Pittsburgh Roentgen Society
Secretary, Dr. Donald H. Rice, Western Pennsylvania Hospital, Pittsburgh 24, Pa. Meets 6:00 P.M. at Webster Hall Hotel on second Wednesday each month, October to May inclusive.

Radiological Section, Baltimore Medical Society
Secretary, Dr. H. Leonard Warres, 2337 Eutaw Place, Baltimore 17, Md. Meets third Tuesday each month, September to May, inclusive.

Radiological Section, Connecticut Medical Society
Secretary, Dr. William A. Goodrich, 85 Jefferson St., Hartford 6, Conn. Meetings are held bi-monthly.

Radiological Section, Medical Society of the District of Columbia
Secretary, Dr. U. V. Wilcox, 915 Nineteenth St., N. W., Washington 6, D. C. Meets Medical Society Library, third Thursday of January, March, May and October at 8:00 P.M.

Radiological Section, Southern Medical Association
Secretary, Dr Roy G. Giles, Temple, Texas.

Radiological Society of Greater Cincinnati
Secretary, Dr. Harry K. Hines, 2508 Auburn Ave., Cincinnati 19, Ohio. Meets monthly from September to June on first Monday of each month at 7:30 P.M. at the Cincinnati General Hospital.

Radiological Society of Hawaii
Secretary, Colonel Alexander O. Haff, M.C., Tripler Army Hospital, Honolulu, T. H. Meets third Friday of each month at Tripler Army Hospital.

Radiological Society of Kansas City
Secretary, Dr. Arthur B. Smith, 800 Argyle Bldg., Kansas City, Mo. Meets third Thursday of each month.

Radiological Society of New Jersey
Secretary, Dr. Nicholas G. Demy, 912 Park Avenue, Plainfield, N. J. Meets annually at Atlantic City at time of State Medical Society and mid-winter at Elizabeth, N. J.

Richmond County Radiological Society
Secretary, Dr. W. F. Hamilton, Jr., University Hospital, Augusta, Ga.

Rochester Roentgen Ray Society, Rochester, N. Y.
Secretary, Dr. A. Gordon Ide, 277 Alexander St., Rochester 7, N. Y. Meets at 8:15 P.M. on the last Monday of each month, September through May, at Strong Memorial Hospital.

Rocky Mountain Radiological Society
Secretary, Dr. Maurice D. Frazer, 1037 Stuart Bldg., Lincoln, Nebr. Next annual meeting, Shirley-Savoy Hotel, Denver, Colo., August 20, 21 and 22, 1953.

St. Louis Society of Radiologists
Secretary, Dr. Francis O. Trotter, Jr., 634 N. Grand Blvd., St. Louis 3, Mo. Meets fourth Wednesday each month, except June, July, August and September.

San Antonio-Military Radiological Society
Secretary, Dr. Hugo F. Elmendorf, Jr., 730 Medical Arts Bldg., San Antonio 5, Texas. Meets Brook Army Medical Center Officers Mess first Monday of each month.

San Diego Radiological Society
Secretary, Dr. C. W. Bruner, 2456 Fourth Ave., San Diego 1, Calif. Meets first Wednesday of each month at the University Club.

San Francisco Radiological Society
Secretary, Dr. I. J. Miller, 2680 Ocean Avenue, San Francisco 27, Calif. Meets quarterly.

Section on Radiology. California Medical Association
Secretary, Dr. Calvin L. Stewart, 2330 First Ave., San Diego 1, Calif.

Section on Radiology, Illinois State Medical Society
Secretary, Dr. George E. Irwin, Jr., 703 N. East St., Bloomington, Ill.

Shreveport Radiological Club
Secretary, Dr. R. W. Cooper, Charity Hospital, Shreveport, La. Meets monthly on third Wednesday, at 7:30 P.M., September to May inclusive.

South Bay Radiological Society
Secretary, Dr. W. H. Graham, 634 East Santa Clara St., San Jose 12, Calif. Meets second Wednesday each month.

South Carolina Radiological Society
Secretary, Dr. William A. Klauber, Self Memorial Hospital, Greenwood, S. C. One meeting with South Carolina Medical Association in May, others arranged by President.

Tennessee Radiological Society
Secretary, Dr. J. M. Frère, Newell Hospital, Chattanooga, Tenn. Meets annually at the time and place of the Tennessee State Medical Association.

Texas Radiological Society
Secretary, Dr. R. P. O'Bannon, 650 Fifth Ave., Fort worth 4, Texas. Next meeting, Dallas, Texas, Jan. 29 and 30, 1954.

University of Michigan Department of Roentgenology Staff Meeting
Meets each Monday evening from September to June, at 7:00 P.M. at University Hospital.

University of Wisconsin Radiological Conference
Secretary, Dr. E. A. Pohle, 1300 University Ave., Madison, Wis. Meets first and third Thursdays 4:00 to 5:00 P.M., September to May, Service Memorial Institute.

Utah State Radiological Society
Secretary, Dr. Angus K. Wilson, 343 S. Main St., Salt Lake City 1, Utah. Meets third Wednesday in September, November, January, March and May.

Virginia Radiological Society
Secretary, Dr. P. B. Parsons, Norfolk General Hospital, Norfolk, Va. Meets annually in October.

Washington State Radiological Society
Secretary, Dr. John N. Burkey, 555 Medical-Dental Bldg., Seattle 1, Wash. Meets fourth Monday of each month from September through May.

Westchester Radiological Society
Secretary, Dr. Clifford C. Baker, Harwood Bldg., Scarsdale, N. Y. Meets on third Tuesdays of January and October and on two other dates.

Wisconsin Radiological Society
Secretary, Dr. Irving I. Cowan, 425 E. Wisconsin Ave., Milwaukee 2, Wis. Special meetings held during year; annual meeting each spring at Madison, Wis.

X-Ray Study Club of San Francisco
Secretary, Dr. Wm. W. Saunders, Veterans Administration Hospital, San Francisco 21, Calif. Meets monthly, third Thursday, at 7:45 P.M., Lane Hall, Stanford University Hospital.

Cuba, Mexico, Puerto Rico and Central America

Sociedad de Radiología y Fisioterapia de Cuba
President, Dr. J. Manuel Viamonte, Hospital Mercedes, Habana, Cuba. Meets monthly in Habana.

Sociedad Mexicana de Radiologia y Fisioterapia
General Secretary, Dr. D. P. Cossio, Marsella No. 11, Mexico, D. F. Meets first Monday of each month.

Asociación Puertorriqueña de Radiología
Secretary, Dr. Rafael A. Blanes, Ave. Ponce de Leon 1175, Santurce, P. R.

Sociedad Radiológica Panameña
Secretary, Dr. L. Arrieta Sanchez, Apartado No. 86, Panama, R. de P. Meets monthly in a department of radiology of a local hospital, chosen at preceding meeting.

British Empire

British Institute of Radiology Incorporated with the Röntgen Society
Ordinary meeting, on the Thursday preceding the third Friday, October to May at 8:15 P.M.
Medical Members' meeting, on third Friday in each month at 5:00 P.M., 32 Welbeck St., London, W 1.

Faculty of Radiologists
Honorary Secretary, Dr. J. F. Bromley, 45, Lincoln's Inn Fields, London, W.C.2, England.

Section of Radiology of the Royal Society of Medicine (Confined to Medical Members)
Meets third Friday each month at 4:45 P.M. at the Royal Society of Medicine, 1 Wimpole St., London.

Canadian Association of Radiologists
Honorary Secretary-Treasurer, Dr. D. L. McRae, Suite 305, 1555 Summerhill Avenue, Montreal 25, Que. Meetings January and June.

Section of Radiology, Canadian Medical Association
Secretary, Dr. C. M. Jones, Inglis St., Ext. Halifax, N. S.

Société Canadienne-Française d'Electrologie et de Radiologie Médicales
Secretary, Dr. Origéne Dufresne, 4120 Ontario St., East, Montreal, P. Q.

College of Radiologists (Australia and New Zealand)
Honorary Secretary, Dr. Alan R. Colwell, c/o British Medical Agency, 135 Macquarie St., Sydney, N.S.W.

South America

Asociacion Argentina de Radiologia
Secretary, Dr. Lidio G. Mocsa, Avda. Gral. Paz 151, Córdoba, Argentina. Meetings held monthly.

Sociedad Argentina de Radiologia, Junta Central, Buenos Aires
Secretary, Dr. Oscar F. Noguera, Santa Fe 1171, Buenos Aires. Meetings are held monthly.

Sociedad Argentina de Radiologia, Filial del Litoral, Sede, Rosario
President, Dr. Francisco P. Cifarelli. Meets monthly second Wednesday, 19 ha 663 Italia St., Rosario, Santa Fe.

Sociedad Argentina de Radiologia, Filial del Sur, Sede, La Plata
President, Prof. Dr. Jose P. Uslenghi, La Plata. Meets monthly.

Sociedad Argentina de Radiologia, Filial del Centro Sede, Cordoba
President, Prof. Dr. David L. Caro, Corro 86, Cordoba. Meets monthly.

Sociedad Argentina de Radiologia, Filial del Norte, Sede, Tucuman
President, Dr. Julio Mendez Valladares, Rivadavia 358, Tucuman. Meets monthly.

Sociedad Argentina de Radiologia, Filial de Cuyo Sede, Mendoza.
President, Dr. J. A. Orfila, Hospital Central, Mendoza. Meets monthly.

Sociedade Brasileira de Radiologia Medica
Secretary, Dr. Nicola Caminha, Av. Mem de Sa, Rio de Janeiro, Brazil. Meets monthly, except during January, February and March.

Sociedade Brasileira de Radioterapia
Secretary, Dr. Oscar Rocha von Pfuhl, Av. Brigadeiro Luiz Antonio, 644 São Paulo, Brazil. Meets monthly on second Wednesday at 9:00 P.M. in São Paulo at Av. Brigadeiro Luiz Antonio, 644.

Sociedad Colombiana de Radiologia
Secretary, Dr. Luis E. Lozano B., Carrera 12 No. 20–69, 6º piso, Bogota, Colombia. Meets last Thursday of each month.

Sociedad Peruana de Radiologia
Secretary, Dr. Julio Bedoya Paredes, Apartado 2306, Lima, Peru. Meets monthly except during January,

February and March, at Asociación Médica Peruana "Daniel A. Carrión," Villalta, 218, Lima.

Sociedad de Radiologica, Cancerologia y Fisica Medica del Uruguay
Secretary, Dr. Arias Bellini, Av. Agraciada 1464, Piso 13, Montevideo, Uruguay.

Continental Europe

Société Belge de Radiologie
General Secretary, Dr. S. Masy, 111 Avenue des Allies, Louvain, Belgium. Meets monthly, second Sunday at Maison des Médecins, Brussels.

Société Française d'Electro-Radiologie Médicale, and its branches: Société du Sud-Ouest, du Littoral Méditerranéen, du Centre et du Lyonnais, de l'Ouest, de l'Est, et d'Alger et d'Afrique du Nord
Secretary-General, Dr. A. Dariaux, 9 bis, Boulevard Rochechouart, Paris IX^{e}, France.

Ceskoslovensk společnost pro rëntgenologii a Radiologii v Praze
Secretary, Dr. Roman Bláha, Praha XII, stát. nemocnice, Czechoslovakia. Meets monthly except during July, August, and September. Annual general meeting.

Polish Society of Radiology
Secretary, Dr. L. Zgliczynski, 59 Nowogrodzka St., Warsaw, Poland.

Gdansk Section, Polish Society of Radiology
Secretary, Dr. A. Smigielska, Akademia Lekarska, Gdansk. Meets monthly last Sunday at 10:30, X-Ray Dept., Akademia Gdansk.

Wroclaw Section Polish Society of Radiology
Secretary, Dr. R. Marciniak, Akad. Medyczna Wroclaw, 68 Curie-Skłodowska St., Wrocław, Poland. Meets first Sunday of each month, X-Ray Department, Akademia Medyczna Wroclaw.

Societatea Romana de Radiologie si Electrologie
Secretary, Dr. Oscar Meller, Str. Banual Mărăcine, 30, S. I., Bucuresti, Roumania. Meets second Monday in every month with the exception of July and August.

All-Russian Roentgen Ray Association, Leningrad
USSR in the State Institute of Roentgenology and Radiology, 6 Roentgen St.
Secretaries, Drs. S. A. Reinberg and S. G. Simonson. Meets annually.

Scandinavian Roentgen Societies
The Scandinavian roentgen societies have formed a joint association called the Northern Association for Medical Radiology, meeting every second year in the different countries belonging to the Association.

Sociedad Espanola de Radiologia y Electrologia
Secretary, Dr. J. Martin-Crespo, Fuencarral, 7. Madrid, Spain. Meets monthly in Madrid.

Schweizerische Röntgen-Gesellschaft (Société Suisse de Radiologie)
Secretary, Dr. Max Hopf, Effingerstrasse 47, Bern, Switzerland.

Deutsche Roentgen-Gesellschaft
Secretary, Dr. Peter Kröker, (22a) Essen-Helsingen, Westpreussenstrasse 21. Meets annually in different towns.

Societa Italiana di Radiologia Medica
Secretary, Prof. Mario Ponzio, Ospedale Mauriziano. Torino, Italy. Meets biannually.

India

Indian Radiological Association
Secretary, Dr. R. F. Sethna, Navsari Building, Hornby Road, Bombay 1, India.

ROCKY MOUNTAIN RADIOLOGICAL SOCIETY

The Fifteenth Annual Mid-Summer Conference of the Rocky Mountain Radiological Society will be held in Denver, Colorado, at the Shirley-Savoy Hotel on Thursday, Friday, and Saturday, August 20, 21, and 22, 1953.

The following program has been arranged:

Guest Speakers

David G. Pugh, M.D., Rochester, Minnesota
Merrill C. Sosman, M.D., Boston, Massachusetts
Sven Roland Kjellberg, M.D., Stockholm, Sweden
Brigadier D. B. McGrigor, London, England
Frederic E. Templeton, M.D., Seattle, Washington
Vincent W. Archer, M.D., University, Virginia
John Caffey, M.D., New York, New York
Edward J. McCormick, M.D., Toledo, Ohio

Thursday Morning, August 20

8:00–10:00 A.M. Registration
Lincoln Room Lobby, Shirley-Savoy Hotel.

10:00–10:30 A.M. Addresses of Welcome, on behalf of:
Rocky Mountain Radiological Society. H. Milton Berg, M.D., Bismarck, North Dakota. President.
American College of Radiology, and The Radiological Society of North America. Ira H. Lockwood, M.D., Kansas City, Missouri. President-Elect, The Radiological Society of North America, Chairman of Board of Chancellors, American College of Radiology.
American Roentgen Ray Society. Charles L. Martin, M.D., Dallas, Texas. President.
Colorado State Medical Society. William A. Liggett, M.D., Denver, Colorado. President.
Denver Medical Society. Lumir R. Safarik, M.D., Denver, Colorado. President.

10:30–11:00 A.M. "The Visualization of Tumors of Soft Tissue Structures by the Use of Ultra High Frequency Sound Waves." Douglas R. Howry, M.D., Denver, Colorado.

11:00–11:30 A.M. "Myelofibrosis and Myelosclerosis." David G. Pugh, M.D., Rochester, Minnesota.

11:30–12:00 P.M. "Roentgen Studies in Patients with Mitral Disease." Merrill C. Sosman, M.D., Boston, Massachusetts.

12:00–12:30 P.M. "Value of Heart Volume Determinations." Sven Roland Kjellberg, M.D., Stockholm, Sweden.

12:30–1:50 P.M. Luncheon with Guest Speakers. H. Milton Berg, M.D. President, Rocky Mountain Radiological Society, Presiding.

Thursday Afternoon, August 20

H. Milton Berg, M.D., President, Rocky Mountain Radiological Society, Presiding.

2:00–2:30 P.M. "Reminiscences of Forty-Four Years of Radiology in the British Army Medical Service." Brigadier D. B. McGrigor, London, England.

2:30–3:00 P.M. "Tumors of the Small Bowel." R. F. Nuessle, M.D., Bismarck, North Dakota.

3:00–3:30 P.M. Period for Visiting Exhibits.

3:30–4:00 P.M. "Muscular Contraction Patterns in Certain Esophageal Conditions." Frederic E. Templeton, M.D., Seattle, Washington.

4:00–4:30 P.M. "Lesions in and about the Second Portion of the Duodenum." Lester D. Shook, M.D., Ira H. Lockwood, M.D., and Arthur B. Smith, M.D., Kansas City, Missouri.

4:30–5:00 P.M. "The Roentgen Findings in Strangulation Obstruction of the Small Bowel." Harry Z. Mellins, M.D., Detroit, Michigan, and Leo G. Rigler, M.D., Minneapolis, Minnesota.

5:00 P.M. Executive Session—For all members of the Society.

Thursday Evening, August 20

6:00 P.M. Informal Guest Speakers' Dinner; Everyone Invited.

8:00 P.M. Joint Meeting with Denver Medical Society. Lumir R. Safarik, M.D., President, Denver Medical Society. H. Milton Berg, M.D., President, Rocky Mountain Radiological Society, Presiding.

Film Reading:
Panel:
Merrill C. Sosman, M.D., Moderator, Boston, Massachusetts
Vincent W. Archer, M.D., University, Virginia
John Caffey, M.D., New York, New York

Sven Roland Kjellberg, M.D., Stockholm, Sweden
David G. Pugh, M.D., Rochester, Minnesota
Frederic E. Templeton, M.D., Seattle, Washington

Friday Morning, August 21

Warren B. West, M.D., Ogden, Utah, First Vice-President, Rocky Mountain Radiological Society, Presiding.

9:00–9:30 A.M. "Isodose Data for Intracavity Roentgen Therapy." E. Dale Trout, B.D., Sc.D., John P. Kelley, B.S., and Arthur C. Lucas, Milwaukee, Wisconsin.

9:30–10:00 A.M. "Recent Developments in Atomic Energy of Interest to Radiologists." Paul C. Aebersold, Oak Ridge, Tennessee.

10:00–10:30 A.M. "Protection of Radiological Personnel During Diagnostic Procedures." Vincent W. Archer, M.D., University, Virginia.

10:30–11:00 A.M. "Gastric Carcinomas, Missed." Frederic E. Templeton, M.D., Seattle, Washington.

11:00–11:30 A.M. "Roentgen Findings in Hemochromatosis." Merrill C. Sosman, M.D., Boston, Massachusetts.

11:30–12:30 P.M. "Carcinoma of the Mouth and Neck." Charles L. Martin, M.D., Dallas, Texas.

12:30–1:50 P.M. Two separate luncheons with half of guest speakers in each room. Galen M. Tice, M.D., Kansas City, Kansas, and Howard B. Hunt, M.D., Omaha, Nebraska, Presiding.

Friday Afternoon, August 21

Donald H. Breit, M.D., Sioux Falls, South Dakota, Second Vice-President, Rocky Mountain Radiological Society, Presiding.

2:00–2:30 P.M. "The Life Cycle of the Nasal Accessory Sinuses." W. Walter Wasson, M.D., Denver, Colorado.

2:30–3:00 P.M. "Pulmonary Cysts of Early Infancy; Their Natural Regression." John Caffey, M.D., New York, New York.

3:00–3:30 P.M. Period for Visiting Exhibits.

3:30–4:00 P.M. "Neurogenic Dysfunction of the Alimentary and Urinary Tracts." Robert Parker Allen, M.D., Denver, Colorado.

4:00–4:30 P.M. "Obstructive Lesions of the Gastrointestinal Tract in Infants." Edward B. Singleton, M.D., Houston, Texas.

4:30–5:00 P.M. "Urethrocystography in Children." Sven Roland Kjellberg, M.D., Stockholm, Sweden.

5:00 P.M. Executive Session—For all members of the Society.

Friday Evening, August 21

6:30 P.M. Social Hour.

7:30 P.M. Informal Banquet.

Toastmaster: Kenneth D. A. Allen, M.D., Denver, Colorado.

Address: Edward J. McCormick, M.D., Toledo, Ohio. President, American Medical Association

Dancing; Entertainment

Saturday Morning, August 22

H. Milton Berg, M.D., Bismarck, North Dakota, President, Rocky Mountain Radiological Society, Presiding.

9:00–9:15 A.M. Installation of Officers.

9:15–9:40 A.M. "Low Back Pain from the Viewpoint of the Radiologist." Ira H. Lockwood, M.D., Kansas City, Missouri.

9:40–10:00 A.M. "The Roentgen Manifestations of Early Joint Disease." Everett L. Pirkey, M.D., Doris E. Pipkin, M.D., and Jack Moshein, M.D., Louisville, Kentucky.

10:00–10:30 A.M. Period for Visiting Exhibits.

10:30–11:00 A.M. "The Skeletal Features of Gargoylism (Dysostosis Multiplex)." John Caffey, M.D., New York, New York.

11:00–11:30 A.M. "Malacia Disease of Bone." David G. Pugh, M.D., Rochester, Minnesota.

11:30–12:00 P.M. "Selected Medical and Surgical Radiological Problems in the Royal Army Medical Corps." Brigadier D. B. McGrigor, London, England.

12:00 Noon Luncheons

Vernon L. Bolton, M.D., Colorado Springs, Colorado, and Angus K. Wilson, M.D., Salt Lake City, Utah, Presiding.

Saturday Afternoon, August 22

4:00 P.M. Annual Picnic—Pine Gables Ranch. Everyone Invited.

COURSE ON CLINICAL APPLICATIONS OF RADIOISOTOPES

The Special Training Division of the Oak Ridge Institute of Nuclear Studies has scheduled an advanced course covering the clinical

applications of radioisotopes to be held from September 14–25, 1953. This advanced course, part of the continuing series offered by the Institute, is the second to be concerned with the medical uses of isotopes. The first was given in March, 1951.

Participation will be limited essentially to those physicians who have had clinical experience with radioisotopes.

Subjects to be discussed in the course include tumor localization, circulatory volumes and outputs, fluid and electrolyte spaces, therapy of blood diseases, theory of radiation dosimetry, radioactivity measurement, gold-198 and other colloids, interstitial and surface applications, teletherapy, iodine-131 in diagnosis and therapy, and external counting.

The course will consist of lectures, clinics, and exhibits of equipment. Speakers have been selected from among the leaders in the specific fields of interest.

Additional information and application blanks may be obtained from the Special Training Division of the Institute, P.O. Box 117, Oak Ridge, Tennessee.

ASOCIACIÓN PUERTORRIQUEÑA DE RADIOLOGÍA

At the meeting of the Asociación Puertorriqueña Radiología held at Santurce, Puerto Rico, on February 17, 1953, the following new officers were elected: *President*, Dr. Carlos Guzman Acosta; *Vice President* and *Treasurer*, Dr. José Landrón; *Secretary*, Dr. Rafael A. Blanes, Ave. Ponce de Leon 1175, Santurce, Puerto Rico.

SOUTH CAROLINA RADIOLOGICAL SOCIETY

At a recent meeting of the South Carolina Radiological Society the following officers were elected for the coming year: *President*, Dr. M. E. Parrish, Sumter, S. C.; *Vice President*, Dr. Augusta Willis, Charleston, S. C.; *Secretary-Treasurer*, Dr. William A. Klauber, Greenwood, S. C.

BOOK REVIEWS

Books sent for review are acknowledged under: Books Received. This must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interest of our readers as space permits.

Diagnostic and Experimental Methods in Tuberculosis. By Henry Stuart Willis, M.A., M.D., F.A.C.P., Superintendent and Medical Director, North Carolina Sanatoria, McCain, North Carolina, etc.; and Martin Marc Cummings, M.D., F.C.C.P., Director, Tuberculosis Research Laboratory, Lawson Veterans Administration Hospital, Veterans Administration, Chamblee, Georgia, etc. Second edition. Cloth. Price, $10.00. Pp. 373, with numerous illustrations. Charles C Thomas, Publisher, 301 East Lawrence Avenue, Springfield, Illinois, 1952.

This is a well written book which is enjoyable reading by contrast with most books on laboratory procedures. It contains information which is useful to the novice as well as to the experienced phthisiologist. The authors' interpretation as to "why," not just "what and how" for doing various laboratory procedures is particularly valuable. Of necessity, this type of approach increases the size of the book in excess of that which would be necessary for a simple descriptive manual. The clinical aspects of the diagnostic and experimental methods are especially well handled. Numerous minor but practical aspects of procedure are stressed which could only indicate practical experience on the part of the authors. These assets make the book a valuable asset to the library of the clinician as well as the laboratory diagnostician.

John H. Moyer, M.D.

Die generalisierten Tuberkulosen. Von Dr. med. F. Schmid, Heidelberg. Paper. Price, DM 24.-. Pp. 230, with 51 illustrations. Georg Thieme, Diemershaldenstrasse, 47, Stuttgart, Germany (Grune & Stratton, Inc., New York, New York), 1951.

This book is a scholarly work on disseminated forms of tuberculosis and should be of great interest to the phthisiologist. The author, after a brief historical review of experimental and clinical investigations, discusses in some detail the pathogenesis of tuberculous dissemination. He cites the incidence of bacteremia in tuberculosis of various organ systems, and describes the relationship of the tubercle bacillus in blood and tissues to the defense mechanism of the mesenchymal tissues of the host. He lists the cellular elements employed by the body, and discusses the relationship of reticuloendothelial system, immunity, and allergy.

The major portion of the book is devoted to a discussion of several types of disseminated tuberculosis, including acute and chronic miliary tuberculosis, caseous pneumonia, and tuberculous meningitis. In a practical vein, the writer describes the symptomatology, histopathology, immunological reaction, and in several instances the roentgen aspect. In this section also is an excellent discourse on sarcoidosis, including historical data, its relationship to tuberculosis, etiology, symptomatology, and morphological studies.

In the final portion of the book the author lists in table form the differential roentgen diagnostic features of miliary tuberculosis. An extensive bibliography is appended.

T. A. Gross, M.D.
E. A. Pohle, M.D.

Geschwülste des Ohres und des Kleinhirnbrückenwinkels. Von Dr. med. K. Graf, Priv.-Doz. für Ohren-Nasen-Halsheilkunde an der Universität Zürich. Cloth. Price, DM 43.-. Pp. 283, with 132 illustrations. Georg Thieme, Diemershaldenstrasse, 47, Stuttgart, Germany (Grune & Stratton, Inc., New York, New York), 1952.

In his book on "Tumors of the Ear and the Cerebellar Angle" Dr. K. Graf of Zürich, Switzerland, gives a comprehensive review of the clinical and pathological, as well as the anatomical picture which presents itself in tumors involving either the ear or the cerebellar pontine angle.

His material consists of 67 cases described in extenso, including history, thorough physical examination, laboratory findings such as lumbar puncture and roentgenography of the skull, particularly in the Stenvers position, operative findings and subsequent course. As an introduction to the actual description of the cases, Dr. Graf thoroughly reviews the literature on tumors of the cerebellar pontine angle by pay-

ing considerable attention to the acoustic tumors, and discusses in detail the symptomatology from the involvement locally as well as the neighboring symptoms. The roentgen and spinal fluid findings are also discussed as is the particular pathology found in cases of acoustic tumors. As a matter of fact, by far the greatest amount of space is devoted to the acoustic tumors, although such tumors as neurinoma of the trigeminus, facial and glossopharyngeal vagus nerves are also considered. Other tumors discussed are the meningiomas, the angiomatous tumors of the ear, carcinoma and sarcoma, static tumors of the petrous bone, and cholesteatoma. Of the 67 cases, 38 were single acoustic tumors, one was bilateral.

The entire material is dealt with in very competent manner, although the conclusion to be drawn is left more or less to the reader. The one important exception is that even in so-called radical extirpation, where the internal acoustic meatus has been completely freed of the tumor, the inner ear may contain tumor cells which the author feels must necessarily be removed in order to insure a complete cure.

There are 132 excellent illustrations. The majority of them depict sections of the tumors, the sections going through the tumor and the petrous portion of the temporal bone at the level of the internal acoustic meatus.

This book is exact and worth while. It can be recommended to anyone who is interested in tumors of the ear and the cerebellar angle.

Aage Nielsen, M.D.

Klinische Elektrokardiographie. Lehrbuch für Studierende und Ärzte. Von Dr. Max Holzmann, Zürich. 2., erweiterte und verbesserte Auflage. Cloth. Price, DM 69.60. Pp. 652, with 302 illustrations. Georg Thieme, Diemershaldenstrasse, 47, Stuttgart, Germany, 1952.

The first edition of this work was translated into Italian and Spanish and of the second edition a translation into English is announced. The Anglo-American and French literature is very adequately covered. The theory and physiologic aspects, including a detailed presentation of vector analysis of the electrocardiogram, are very adequately presented. Abnormal electrocardiograms are discussed under the following headings: technical errors; situs inversus; fixation of the heart; abnormal amplitudes; abnormal findings with respect to the atrial and ventricular portion, including the length of the electrical systole; preponderance; inflammatory, toxic, allergic, endocrine and vitamin disturbances; primary myocardial alterations; the influence of digitalis; ischemia—coronary insufficiency—infarction group; pericarditis; pulmonary embolism; orthostatic and neurovegetative effects. The subsequent presentation of the disturbances of rhythm includes valuable therapeutic remarks. There follow discussions of the W-P-W syndrome and of the electrocardiographic findings in trauma of the heart, in systemic diseases of the neuromuscular system and finally in the dying heart.

Detailed electrocardiographic analysis and evaluation is always well tempered by the author's mature clinical judgment. The value of a number of case presentations is enhanced by giving the postmortem data.

The line drawings are very instructive and technically superb. The publisher deserves high commendation for the excellency of both the printing and the reproduction of the photographic material. The quality of reproduction depends upon a number of factors—paper, ink, speed of printing process and last, but not least, fineness of the screen—and the reproductions in many medical books and journals in our country could be remarkably improved if we could persuade the publishers to use finer screens in spite of the slightly higher cost involved. The reviewer stresses this point because few medical authors and editors seem to be aware of the technical procedures involved in reproducing scientific illustrations and therefore cannot effectively exert pressure on publishers to improve the quality of illustrations.

Hugo Roesler, M.D.

The Story of the Adaptation Syndrome (Told in the Form of Informal, Illustrated Lectures). By Hans Selye, M.D., Ph.D. (Prague), D.Sc. (McGill), F.R.S. (Canada), Professor and Director of the Institut de Médecine et de Chirurgie expérimentales, Université de Montréal. Fabrikoid. Price, $4.50. Pp. 225, with numerous illustrations. Acta, Inc., 5465 Decarie Boulevard, Montreal 29, Quebec, Canada, 1952.

The name of Hans Selye is so well known in the scientific world that any thoughts which he might have or publications which he might make concerning his well known theories of the

"Adaptation Syndrome" are always welcome.

There has just appeared from the press of the Acta Medical Publishers "The Story of the Adaptation Syndrome," by Hans Selye.

The publication is based upon seven informal lectures, and in these lectures Selye traces the development of his theory of stress from an accidental discovery to a clearly defined concept which he has elaborated in more extensive books.

This book is written in simple conversational style which makes it not only enjoyable reading but it is given in such a way that his theory can be more completely appreciated.

This book should make a great appeal and prove beneficial reading for not only physicians, but research workers, medical students and those interested in the biological sciences. It should be in the hands of all of those who are interested in medicine and its allied subjects.

L. Reynolds, M.D.

ABSTRACTS OF RADIOLOGICAL LITERATURE

Department Editor: T. LEUCUTIA, M.D., Harper Hospital, Detroit 1, Michigan

INDEX TO ABSTRACTS

ROENTGEN DIAGNOSIS

BLOOD AND LYMPH SYSTEM

KAISER, K., and THURN, P.: Roentgen kymography of the aorta 167
POUTASSE, E. F., ENGEL, WILLIAM J., and ROOT, J. C.: Translumbar aortography 167
PETIT-DUTAILLIS, D., PERTUISET, B., and ROUGERIE, J.: Percutaneous carotid angiography 167
GOODWIN, J. F., STEINER, R. E., and LOWE, K. G.: The pulmonary arteries in mitral stenosis demonstrated by angiocardiography 168
BÄTZNER, K., and BRACHT, H.: Technique of arteriography of the extremities 168
TIDY, H.: Banti's disease and splenic anaemia. 169
HUNT, A. H.: The surgical treatment of Banti's syndrome 169
REILLY, E. B., *et al.:* Familial chronic lymphatic leukemia 169
CHANDLER, G. N.: Lymphangitis carcinomatosa 169
MÖRL, F.: The importance of the sternal lymph chain in the metastatic spread of breast cancer 170
CASSIMOS, C., and ZANNOS, L.: Congenital hypoplastic anemia associated with multiple developmental defects (Fanconi's syndrome) 170
BIRKNER, R., and FREY, J. G.: Roentgenological, hematological and pathological-anatomical bases in leuko-erythroblastic anemia with myelosclerosis; Vaughan type 171
PELLER, S., and PICK, P.: Leukemia and other malignancies in physicians 172
WETZEL, U., and HEUCK, F.: A contribution to the knowledge of pulmonary arteriovenous aneurysm and of similar malformations 172
DENSTAD, T.: Abdominal aortography 172
LARSSON, H., and PALMLÖV, A.: Abdominal aortography with special reference to its complications 173
MACEWEN, K. F.: Abdominal aortic aneurysm 173
RABAIOTTI, A.: The value and indication for intraosteal phlebography in the study of venous lesions of the lower extremity 173
PIRASTU, E.: Osteomyelography 174
LEMAIRE, A.: Intraarterial injections of oxygen; a new method of diagnosis and treatment of arteritis of the extremities 174
TORI, G.: First experiments in epihepatophlebography in man 174
LÉGER, J.-L.: Preliminary report on the use of a new contrast medium: Angiopac 175
HOOKS, C. A., and GRAVES, O. H.: Experiences with percutaneous trans-femoral renal arteriography 175

GENERAL

HENDERSON, J. L., *et al.:* Pathology and biochemistry of gargoylism 175
MAUDSLEY, R. H.: Case of myositis ossificans progressiva 176

RADIATION THERAPY

STALLARD, H. B.: Irradiation of retinoblastoma (glioma retinae) 176
TUCKER, G.: Diagnosis and treatment of cancer of the larynx 176
GARLAND, L. H., and SISSON, M. A.: Roentgen therapy of carcinoma of the larynx 176
MAYER, E., and ROSWIT, B.: Newer palliative measures in the management of inoperable bronchogenic carcinoma 177
KAAE, S.: Value of preoperative roentgen irradiation in operable breast cancer 178
NOLAN, J. F., and DU SAULT, LUCILLE: Elimination of untoward radiation sequelae in the treatment of carcinoma of the uterine cervix. 178
PAYNE, F. L.: Role of radiation and of surgery in the management of uterine carcinoma ... 179
CURRIE, D. W.: Association of radium and surgery in the treatment of carcinoma of the cervix 179
REDMAN, T. F.: Stump carcinoma 180
HUNDLEY, J. M., JR., DIEHL, W. K., and KARDASH, T.: Treatment of benign uterine bleeding with intracavitary radiation 180
KIMBROUGH, J. C.: Tumors of the testicle 180
LAWRENCE, K. B., and LENSON, N.: Reticulum cell sarcoma 181
MUELLER, H. L., and FLAKE, C. G.: Irradiation of the nasopharynx in children with infectious asthma 181
KOCH, W., and RESKE, W.: Results from intravenous administration of thorium X in treatment of ankylosing spondylitis (M. Bechterew) 181
BROWN, J. B., and FRYER, M. P.: Hemangiomas: treatment and repair of defects 182
MCCORMICK, N. A.: A study of the complications resulting from treatment of cancer of the cervix 182

ROENTGEN DIAGNOSIS

Blood and Lymph System

Kaiser, K., and Thurn, P. Beitrag zur Röntgenkymographie der Aorta. (Roentgen kymography of the aorta.) *Fortschr. a. d. Geb. d. Röntgenstrahlen ver. m. Röntgenpraxis*, July, 1952, *77*, 28–37.

The authors have studied the pulsation of the aorta by roentgen kymographic methods and show that the variations in thrust of the wall are due to a change in aortic volume, rather than to the usual assumption that stroke volume, amplitude of blood pressure, elasticity of the wall and its effect upon the resistance to the blood flow, play a part. The blood pressure has only a small role in the amplitude of pulsation since it is shown that larger excursions of the wall occur only when the volume of the blood flow in the major circuit is increased.—*Paul C. Swenson, M.D.*

Poutasse, Eugene F., Engel, William J., and Root, Joseph C. Translumbar aortography. *Cleveland Clin. Quart.*, July, 1952, *19*, 105–115.

The history and application of translumbar aortography to renal lesions and vascular pathology of the aorta are briefly discussed.

While the technique of syringe injection employing either 75 per cent neo-iopax or 70 per cent diodrast is no different than that described in the literature, the importance of making a preliminary roentgenogram after insertion of the needle and the injection of 10 cc. of 35 per cent diodrast is stressed.

Over a period of two years, 100 studies were performed without serious complications at the Cleveland Clinic.

The authors illustrate and discuss several conditions in which aortography was most useful in making a diagnosis. Among these was the visualization of aberrant vessels producing hydronephrosis. The blood supply of certain congenital anomalies of the kidneys is described because of its practical value to the urologist.

The differentiation between cysts and malignant tumors of the kidney was possible by aortography. The malignant tumor showed increased vascularity with "pooling" of the opaque medium, while cysts exhibited an avascular area with displacement of the vessels around the periphery. Benign adenomas of the renal parenchyma and papillary and squamous cell carcinomas of the renal pelvis did not reveal any characteristic changes of the vascular pattern.

The reduction in the vascular supply of the kidney is suggestive of an old inflammatory process, such as chronic pyelonephritis. When non-function is present and the ureter cannot be catheterized, a study of the vascular pattern within the kidney will give information concerning the diagnosis and amount of good renal parenchyma present.

Retroperitoneal tumors, such as a large adrenal carcinoma, were diagnosed by this method. No claims are made to the diagnosis of small tumors or demonstration of adrenal hyperplasia.

A large left upper quadrant mass was shown to be spleen by this method. Here, visualization was poor by urography and the ureter could not be catheterized. Hodgkin's sarcoma of the spleen was found at operation.

The last part of the paper is devoted to further illustration and brief discussion of aneurysms and occlusions of the aorta.—*A. William Finestone, M.D.*

Petit-Dutaillis, D., Pertuiset, B., and Rougerie, J. L'angiographie carotidienne percutanée; technique, indications, résultats (étude portant sur 1034 injections). (Percutaneous carotid angiography; technique, indications and results [study based on 1,034 injections].) *Presse méd.*, Aug. 2, 1952, *60*, 1091–1092.

The innocuousness and simplicity of the percutaneous injection of the common carotid artery are stressed.

The preparation of the patient comprises: no food by mouth for six hours, injection of phenergan one-half hour before and a sedative such as morphine (intravenously) immediately prior to angiography. The sedated patient is placed on his back with the neck and head flexed dorsally to the maximum and fixed in this position. To puncture the common carotid, an 0.8 mm. needle is inserted at the medial border of the sternocleidomastoid muscle about 3 to 4 cm. above the manubrium sterni, pointing it obliquely deep and upwards. After the injection of 8 to 10 cc. of 45 per cent diiodone, three lateral and one anteroposterior roentgenograms of the skull are taken every other second. Other views could also be used to visualize different vascular segments of the brain. The only complaint of the patient is a transient sensation of heat. Care should be taken that the contrast medium is injected into the lumen of the carotid and not into its wall by ascertaining free flow of the arterial blood into the syringe before injection. Postinjection hematomas are very rare and insignificant.

Contraindications are angina pectoris, malignant arterial hypertension, arteriosclerosis, diffuse arteritis, nontraumatic meningeal hemorrhage and hypersensitivity to iodine (in the experience of the authors, no such case was noted).

The main indications are vascular lesions, cerebral tumors, epilepsy, meningeal hemorrhages after the eighth day of the onset, cranial injuries, hydrocephaly, encephalitis, headaches, vertigo and various other affections.

In certain patients, both common carotids were injected.

The authors had 1 fatal case out of 746 patients which they are sure was due to the injection of novocaine and, hence, do not consider it in their statistics. Thus, only 0.6 per cent of benign and regressive complications, such as transient hemiplegia and aphasia, increase of obnubilation and convulsions were noted.

The conclusion is reached that percutaneous carotid angiography combined with electroencephalography will increase the number of diagnoses of subclinical pathology where symptoms are deficient and ventriculography nonrevealing. It is also stated that deep parieto-occipital and infratentorial lesions should be investigated by vertebral artery angiography as carotid angiography is of no diagnostic value in these regions.—*Jirair N. Sarian, M.D.*

Goodwin, J. F., Steiner, R. E., and Lowe, K. G. The pulmonary arteries in mitral stenosis demonstrated by angiocardiography. *J. Faculty of Radiologists*, July, 1952, *4*, 21–27.

Pulmonary hypertension is frequently associated with mitral stenosis. Direct visualization of the pulmonary vessels by venous angiocardiography was carried out in 12 patients with mitral stenosis.

Angiocardiography was performed in the supine position using a manually operated, gravity-feed cassette changer. Nine frames were exposed at varying intervals depending on the severity of the individual case. Usually the lesser circulation was demonstrated two to five seconds after beginning the injection, and the pulmonary veins and left auricle from eight seconds onward. Patients were prepared with a simple sedative (seconal or sodium amytal, grains 1.5 to 3). Patients who had a rise in jugular venous pressure or who had evidence of pulmonary congestion were excluded as unsuitable risks. Seven of the patients had previously suffered from congestive failure but had recovered at the time of the investigation. A dose of approximately 1 cc. per kg. of body weight of a 70 per cent diiodone solution was used. The injection was made rapidly (3 seconds or less) through a polythene tube, internal diameter of 1.5 to 2 mm., passed by way of an antecubital vein into the upper part of the subclavian vein. A preliminary test dose of 2 cc. diiodone was given intravenously to detect sensitivity.

The patients were graded clinically as follows: Group I, no dyspnea (3); Group II, moderate dyspnea on exertion, (2); Group III, severe dyspnea on exertion (7). No Group IV, dyspnea at rest, patients were included in this series.

Two of the 3 patients in Group I showed enlargement of the main pulmonary artery. Distal to the main trunk the pulmonary arteries did not differ from the normal. The pulmonary circulation time was not prolonged.

In the patients in functional Groups II and III the main pulmonary arteries and the first and second subdivisions were enlarged. Distal to the second subdivision, there was premature narrowing of the branches, which became irregular and tortuous. These cases also seemed to have a more extensive vascular network at the periphery.

In 3 patients in Groups II and III the changes were less well marked. The smaller pulmonary arteries narrowed prematurely in either the inner or middle lung zones. All of the patients in Groups II and III had prolonged pulmonary circulation time. The changes were roughly proportional to the degree of clinical severity.

Increase in resistance at the mitral valve is the basic fault leading to the production of pulmonary hypertension. The raised pressure is not entirely a simple mechanical consequence. By using the pulmonary "capillary" pressure as an indirect measure of left auricular pressure several workers have shown that when severe pulmonary hypertension complicates mitral stenosis the pulmonary artery pressure may be raised to a far greater extent than the left auricular pressure. Here, then, there must be an increase in resistance in the pulmonary arterial tree which could be due to either functional contraction or permanent occlusive changes in the small arteries and arterioles.—*Samuel G. Henderson, M.D.*

Bätzner, K., and Bracht, H. Ein Beitrag zur Technik der Arteriographie der Gliedmassen. (Technique of arteriography of the extremities.) *Fortschr. a. d. Geb. d. Röntgenstrahlen ver. m. Röntgenpraxis*, July, 1952, *77*, 47–54.

Since 1940 the authors have used arteriography of of the extremities in 450 cases. They are convinced that the method offers considerable diagnostic help and information.

They use 30 per cent ioduron or occasionally 70 per cent ioduron. The 30 per cent solution is almost always satisfactory as to the density of the shadows. It causes relatively little pain when injected intra-arterially; general anesthesia was not necessary when it was used. Perabrodil was employed with equally good success lately, with addition of novocain to the solution.

Arteriography was used in 300 cases of injury to the blood vessels, of aneurysms following trauma, and as a check for previous surgery on vessels. In purely arterial aneurysms the contrast material is injected directly into the aneurysmal sac. In large arterial aneurysms and in arteriovenous aneurysms the afferent artery must be injected for best results. In the upper extremity the artery is exposed surgically and injected. In the lower extremity a direct

puncture of the artery just below Poupart's ligament is done.

A special cassette (30 by 90 cm.) has to be used in order to get the entire extremity. When the lower extremity is examined the roentgen tube is tilted 15 degrees in distal direction. When 40 cc. has been injected the arteries of the lower leg are often not filled, especially in cases of vascular disease when it may take twenty to thirty seconds or even up to 100 seconds until the contrast material has entered the arteries below the knee. After injection of 25 cc. an exposure of the thigh is made while the lower portion of the film is covered by lead. Two exposures of the lower leg are made after the injection of the entire 40 cc.

An apparatus is described that uses a three film tunnel (30 by 40 cm.) which allows the taking of serial roentgenograms. This serial study is essential because nonfilling or slow filling of a certain portion of an artery may not be abnormal, as it could appear when only one roentgenogram is made. Embolic closure of an artery or marked arteriosclerotic narrowing may be falsely diagnosed when serial films are not available.

The details of the construction of the serial tunnel are given and it is stated that the apparatus can be made in any carpenter shop.—*Hans W. Hefke, M.D.*

Tidy, Henry. Banti's disease and splenic anaemia; symptomatology and aetiology. *Brit. M. J.*, July 5, 1952, *1*, 1–4.

Banti's disease, in Britain termed splenic anemia when occurring in adults, is described as being characterized by varying degrees of splenomegaly, hypochromic anemia, leukopenia and recurrent hematemesis. In some cases it terminates in cirrhosis of the liver. It is noted pathologically that the liver is always involved whether there is clinical evidence or not. The author points out that the hepatic cirrhosis, the splenomegaly and the blood changes develop independently of one another.

Banti's original but generally disregarded contention that the disease is due to a toxin acting independently on the liver and the spleen is again supported by the author who states that the disease originates from Rh incompatibility in the parents. Clinical evidence is given that Banti's disease and splenic anemia form the syndrome of erythroblastosis fetalis as it appears in survivors at various ages affected in different degrees of severity.—*Walter Herbert, M.D.*

Hunt, Alan H. The surgical treatment of Banti's syndrome. *Brit. M. J.*, July 5, 1952, *1*, 4–9.

The name of Banti's syndrome is loosely applied to patients with large spleens and gastroesophageal varices which frequently bleed. The condition is associated with portal hypertension due to interference with the flow of blood through the liver, in cirrhosis, or to the liver, in extrahepatic obstruction.

The surgical treatment of 68 patients, 12 with extrahepatic obstruction and the others with cirrhosis is discussed. The indications for operation are: (1) gastroesophageal bleeding; (2) hypersplenism; (3) ascites after failure of medical treatment; (4) associated conditions, such as biliary obstruction. The treatment generally consists of reducing the elevated portal venous pressure by surgically constructing a shunt around the obstruction. When portal thrombosis, cavernoma or other extrahepatic obstruction is the cause, a splenectomy is followed by splenorenal anastomosis. This gives excellent results providing the splenic vein is patent and the veins are of sufficient size. In mild cirrhosis a splenorenal or a portacaval anastomosis can be done. Portacaval anastomosis is an efficient method of reducing portal venous pressure and is indicated for gastroesophageal bleeding in the absence of hypersplenism. In advanced cirrhosis, considered unsuitable for the long and difficult shunt operation, common hepatic and splenic arterial ligation offers hope.

Roentgenological portal venography is of great value in demonstrating the exact state of the portal venous tree and whether or not there is an extrahepatic obstruction.

Careful clinical and biochemical assessment is necessary to select cases suitable for portal-systemic venous anastomosis. Those who survive are much improved.—*Walter Herbert, M.D.*

Reilly, Emmett B., Rapaport, Samuel I., Karr, Norman W., Mills, Harold, and Carpenter, Gurth E. Familial chronic lymphatic leukemia. *A.M.A. Arch. Int. Med.*, July, 1952, *90*, 87–89.

The authors report the cases of 3 brothers with chronic lymphatic leukemia.

This article is of interest not only because of the rarity of the condition but because the evaluation of heredity in the causation of this disease in man depends upon such families being on record. This family is believed to be another illustration of the role of genetic predisposition in leukemia in man, a fact long suspected and clearly documented by the studies of Videbaek.

The mode of genetic transmission in this family, in which the disease is confined to several siblings of a single generation, may be explained best by an uncommon recessive gene of high penetrance.—*C. Donald Frey, M.D.*

Chandler, G. N. Lymphangitis carcinomatosa. *Brit. M. J.*, Sept. 20, 1952, *2*, 639–641.

The author points out that the lesion of lymphangitis carcinomatosa has been known for over a cen-

tury. He discusses the high spots in the literature concerning it.

He states that generalized cancerous permeation of the pulmonary lymphatics is much rarer than the nodular, solid or linear metastases more commonly found, and that it gives rise to a far more striking clinical picture characterized by severe progressive unrelenting dyspnea. Though the malignant nature of the condition is often appreciated, the site of the primary growth may not be recognized before death. It is in this group of patients that difficulty in diagnosis arises.

Two new cases are reported, both women, one fifty-four and the other thirty-four years of age. Both had primary carcinoma of the stomach and generalized carcinomatous permeation of the pulmonary lymphatics. In both instances the presenting symptom was severe and progressive dyspnea which dominated the clinical picture and overshadowed other evidence of malignant disease.

The roentgen appearance is felt to depend on a varying combination of (1) linear striation converging radially on the hilus; (2) granular or nodular mottling; (3) reticulation, often very well shown at the periphery and (4) hilar lymph node enlargement. It may be further modified by effusion, atelectasis or congestive heart failure.

A very good discussion is given following this and the author points out that the usual sites of growth which give rise to diffuse pulmonary lymphatic permeation are the stomach, bronchus, breast, prostate and pancreas.—*Robert D. Moreton, M.D.*

Mörl, Franz. Die Bedeutung des sternalen Lymphstranges für die Metastasierung des Mammacarcinoms. (The importance of the sternal lymph chain in the metastatic spread of breast cancer.) *Chirurg*, July, 1952, *23*, 298–300.

The author calls attention to the importance of the sternal chain of lymph nodes in the metastatic spread of breast cancer. He maintains that clinicians are closing their eyes to the problem even though Harold Stiles, in 1892, described this chain and recently Walther, Handley and Thakray, and Thaylor and Mörl have revived interest in it.

To clarify the significance of the sternal lymph node chain, the author repeated the already published dye test. In 34 moribund cases, 1 cc. of dye (india ink) was injected into the breast. At autopsy, performed shortly thereafter, he found dye in the axillary and infraclavicular lymph nodes in 30 cases and in the sternal lymph nodes in 24 cases. It was immaterial which quadrant was injected since dye was found in the sternal lymph nodes in almost all cases injected in the outer quadrant, proving that the outer quadrants of the breast also drain into the sternal lymph nodes.

In a series of 30 cases of carcinoma of the breast of Grade I and II classification (Steinthal) in which, in addition to the radical classical operation, the sternal lymph node chain was removed, he found that 2 out of 10 Grade I cases had metastases in the sternal lymph nodes although the axillary and infraclavicular lymph nodes were not involved. In the Grade II group, 9 out of 20 cases had metastases in the sternal lymph nodes. Interesting, also, is the fact that 2 out of these 11 cases with metastases to the sternal lymph nodes showed evidence of invasion of the carcinoma into the internal thoracic artery and vein.

The author has observed repeatedly and has mentioned in his earlier publications the close relationship of the sternal lymph nodes to the pleura. He now presents 2 cases which show definite evidence of extension from the sternal lymph nodes into the pleura resulting in pleural and pericardial carcinomatosis.

In conclusion, the author stresses the necessity of including the sternal lymph nodes in the treatment plan of breast cancer. It will take a few years before it can be determined whether deep roentgen therapy or surgical removal of the chain or a combination of both methods will lead to any appreciable improvement in the final results.—*Salomon Silvera, M.D.*

Cassimos, Christos, and Zannos, Leda. Congenital hypoplastic anemia associated with multiple developmental defects (Fanconi's syndrome). *A.M.A. Am. J. Dis. Child.*, Sept., 1952, *84*, 347–350.

Fanconi in 1927 first described a syndrome in three brothers, aged three, five and seven years, respectively, who had aplastic anemia, microcephaly, testicular hypoplasia, strabismus, exaggerated deep-tendon reflexes, and a generalized brown pigmentation of the skin. The syndrome is also characterized by multiple congenital malformations associated with hypoplastic anemia. The congenital defects most frequently seen are retardation of growth and development; multiple anomalies of the skeleton, especially absence of radius, thumbs, and carpal bones; syndactyly; microcephaly; microphthalmia; ptosis; strabismus; congenital heart disease; hypogenitalism; cryptorchism and hypospadias.

The blood has the characteristics of hypoplastic anemia, with normocytic and normochromic red blood cells. The leukocyte counts show a neutropenia, with leukocytes being less than 5,000 per cu. mm. The platelets are usually below 50,000 per cu. mm. The bone marrow is hypoplastic and the skin often has a dark color with areas of brown pigmentation.

The authors describe in this paper another case of Fanconi's syndrome in a Greek boy and believe that this is the first such case to be reported in Greece. Their case showed multiple congenital defects, which together with brown pigmentation of the skin and the findings from the bone marrow and the blood, justified their considering it an example of Fanconi's

syndrome. The slight hyperchromia, the anisocytosis, the polychromatophilia and the presence of target cells not commonly seen in hypoplastic anemia, they thought might be traits of Cooley's anemia. This supposition was supported by the fact that the patient's father and brother also showed the traits. Considering the rarity of Fanconi's syndrome and the frequent occurrence of Cooley's anemia in Greece, they think the simultaneous occurrence of the two is probably a coincidence. The patient also had an infectious hepatitis. Probably toxic substances, endogenous or exogenous, not neutralized because of liver damage, act upon the already defective bone marrow to cause the anemia.—*Ralph S. Bromer, M.D.*

Birkner, R., and Frey, J. G. Über die röntgenologischen, hämatologischen und pathologischanatomischen Grundlagen der Anaemia leuco-erythrobastica mit Myelosklerosis vom Typ Vaughan. (Roentgenological, hematological and pathological-anatomical bases in leuko-erythroblastic anemia with myelosclerosis; Vaughan type.) *Fortschr. a. d. Geb. d. Röntgenstrahlen ver. m. Röntgenpraxis*, Sept., 1952, *77*, 287–297.

The authors claim that in leuko-erythroblastic anemia with myelosclerosis there are characteristic changes in the bones which are recognizable on the roentgen film and which, in conjunction with the clinical findings: constitute a distinct entity, permitting a correct intra vitam diagnosis in every case.

In 1936 Vaughan and Harrison described the following criteria of this type of anemia: (1) more or less extensive anemia, with immature white and red blood cells, the total white blood cell count varying from 4,000 to 20,000; (2) usually, a very large spleen with extramedullary metaplasia, which is also noted in the liver, kidneys, adrenals, ovaries, etc.; (3) bone marrow hypoplasia due to advanced myelofibrosis.

Roentgenographically, there is an irregular appearance with sclerotic atrophy and spotty thickening of the spongiosa. There may be occasional confluence of several zones of thickening into larger areas so that the spongy nature of the bone can no longer be recognized. Frequently, there is thinning and some irregular erosion of the inner border of the cortex, particularly in the long bones. Usually, there is only slight osteosclerosis, and periosteal new bone formation is rare.

The clinical course is relatively benign and the patient may live for many years.

Two cases are presented, in one of which the diagnosis was made intra vitam. This patient was a sixty-seven year old female who had a large spleen, Hb. 112 per cent, red blood cell count 6,340,000, white blood cell count 18,300, with many immature cells. Later the hemoglobin dropped to 65 per cent and the red count to 4,140,000. Sternal puncture revealed a marrow poor in cells particularly the white cell elements. Immature erythrocytes were noted. Spleen biopsy showed evidence of metaplasia. The roentgen findings of the bones clinched the diagnosis. The parts examined (upper ends of humeruses and femurs, lower ends of tibias and of radius and ulna) showed lack of normal fine reticular structure, giving almost a cyst-like appearance. Adjacent to spotty atrophic zones there were areas of diffuse thickening. The cortex was thinned and irregularly eroded. Changes indicative of various stages of the disease were encountered in different bones, such as fibrosclerosis of the early stage, streaking and spotty sclerosis of the middle stage, and diffuse sclerosis of the late stage. In this case it appeared that the fibrosclerosis was more extensive than the alterations characteristic of the middle stage.

Markoff believes that bone marrow hyperplasia is associated with osteoporosis (produced by osteoclasis) while hypoplasia is associated with osteosclerosis (the result of osteoblastic function). In osteosclerosis there is a gradual disappearance of the specific bone marrow elements with resulting fibrosis and atrophy. One of the characteristic findings in Vaughan's disease is the presence of bone marrow atrophy with fibrosis of the marrow and sclerosis of the bone.

The other case presented is that of a fifty-three year old man, who had a large spleen, anemia and many immature white and red blood cells. Roentgen examination was not done. Autopsy showed cellular hyperplasia in the femurs and vertebrae and hyperostosis of the ribs and sternum with almost complete disappearance of the bone marrow. Also, there was hyperplasia and stasis of the liver with perihepatic adhesions and moderate hypertrophy of both chambers of the heart with anemic degeneration of the myocardium. The histopathologic study revealed: (1) in the femur: fibrous tissue between the fatty marrow of the bones with erythropoietic and myelopoietic islands. The marked fibrosis and sclerosis of the marrow stood out in particular. Considerable hyalinization and sclerosis of the blood vessels could be seen; (2) in the ribs and sternum: thickening of the bone trabeculae with lines in mosaic arrangement simulating Paget's disease. Little evidence of bone absorption by osteoclasts was present. The marrow space was markedly narrowed with almost complete disappearance of the blood-producing structures; (3) in the spleen: increase in fibrous tissue with numerous giant cells. The lymphatic structure was intact. Myeloid metaplasia was seen in the region of the red pulp. Metaplasia was also present in the lymph nodes and liver.

The etiology of this disease is unknown. Four cell types are affected: the osteoblasts, fibroblasts, hemocytoblasts (erythroblasts and myeloblasts) and the megakaryocytes. The increase in the number of these cells, which arise from the same primitive mesenchyme tissue, may be attributed to an unknown stimulus. Heilmeyer has suggested a failure in differ-

entiation of the reticuloendothelium into osteoblasts and erythroblasts (polyblastic retotheliosis).—*Samuel Richman, M.D.*

PELLER, SIGISMUND, and PICK, PAUL. Leukemia and other malignancies in physicians. *Am. J. M. Sc.*, Aug., 1952, *224*, 154–159.

The authors have investigated the incidence of deaths due to leukemia, as well as other malignancies, in physicians as a group compared with the general population, and in radiologists as compared with non-radiologists. In doing this, they analyzed the causes of deaths of all physicians whose necrologies appeared in the *Journal of the American Medical Association* during the five years 1947 to 1951 inclusive. For comparison they used the official annual report on deaths in the United States, 1948.

In the five year period, 1947–1951, a total of 14,516 physicians were reported dead, but the cause of death was disclosed in only 11,481 cases. The comparison is limited to this latter group with known causes of death. It was found that the percentage of leukemic deaths in physicians as a group was more than twice that in white males of the general population. Using the thirty-five to seventy-four year age group in 1948, 0.6 per cent of all deaths in white males were due to leukemia; and in the total of physicians (1947–1951) the corresponding value was 1.259 per cent. In the sector of radiologists plus dermatologists (1938–1942), the figure was 4.5 per cent. For physicians who were neither radiologists nor dermatologists the value was 1.2 per cent, about twice the figure for white males in the general population. Not all physicians work fluoroscopically or roentgenologically. Thus, the leukemia risk of those who do is much more than twice the normal. It is also pointed out that during the last ten years the radiation risk per 100 radiologists has not increased; rather it has diminished or remained stable. On the other hand, the radiation risk per 100 general practitioners and diagnosticians increased. It is also noted that a higher percentage of non-radiologists was using fluoroscopy in the 1947–1951 period than in 1938–1942. The difference in the leukemia risk as found between radiologists and non-radiologists in former surveys is therefore diminishing.

It is interesting to note that in dial painters and radium miners, radium failed to produce leukemias. The painters had a tremendously increased frequency of bone sarcomas and the miners a 25 to 29 times increased incidence of lung cancers.

The authors discuss the role of the route on entrance of radiation into the body in determining the type of malignant involvement, and the latency periods involved. Tables are included showing the incidence of leukemic and non-leukemic malignancies in various age periods for different population groups.—*D. S. Kellogg, M.D.*

WETZEL, U., and HEUCK, F. Ein Beitrag zur Kenntnis des arterio-venösen Aneurysmas der Lunge und ähnlicher Fehlbildungen. (A contribution to the knowledge of pulmonary arteriovenous aneurysm and of similar malformations.) *Fortschr. a. d. Geb. d. Röntgenstrahlen ver. m. Röntgenpraxis*, Sept., 1952, *77*, 335–343.

The clinical and roentgenologic findings of a patient with an arteriovenous aneurysm in the right lower lobe are given in detail. Multiple telangiectases were present in other parts of the body, including the skin, mouth and nose, and possibly also in the stomach and brain, since there was occult blood in the stools and a jacksonian attack was observed once. Probably because of these sources of bleeding, there was no polycythemia; on the contrary, a secondary anemia was recorded. Roentgenologically, a coin lesion in the right base was noted and was identified as a vascular malformation by its continuity with the hilar vessels. Laminagraphy proved to be especially valuable for this demonstration.

More briefly, the authors also review similar vascular malformations of the lungs, such as diffuse ectasia of one branch of the pulmonary artery.

This scholarly presentation is well illustrated by roentgenographic reproductions of very good quality.—*Albert Oppenheimer, M.D.*

DENSTAD, TORFINN. Abdominal aortography. *Acta radiol.*, Sept., 1952, *38*, 187–198.

The author's material consists of 21 cases from Akershus County Hospital and 76 from Aker Hospital in which abdominal aortography was performed. He goes on to discuss what can be gained from such an examination and the pathologic changes that one can expect to see.

1. *Lesions of Arteries.* Five cases in which there was an aberrant renal artery were found; 2 aneurysms and 2 thromboses were discovered. Five cases of renal dysplasia (ectopic kidney or agenesia) were revealed by an atypical course or absence of the renal artery.

Aortographic studies show whether there is atrophy or hypertrophy of the arteries so that valuable information respecting the function of the organ is ascertained. The blood supply to the kidneys is of particular interest and in aortography there is the advantage of being able to compare the two sides. Important information may be obtained in cases of hypertension even though the "Goldblatt kidney" does not play as important a role in the genesis of hypertension as was at first believed.

2. *Displacement of Arteries.* Hydronephrosis was revealed in 2 cases in which there was no function and in which retrograde pyelography could not be performed. Renal cysts (15 cases) usually force the

vessels apart and appear as poorly vascularized areas. However, cysts are probably better depicted by deformation of the urogram or retrograde pyelogram than by the aortogram.

3. *Malignant Tumors.* These are usually richly vascularized with numerous newly formed pathologic vessels. The author's 10 cases of carcinoma showed a characteristic picture in which there were numerous blood vessels of irregular caliber and course with slow circulation and with retention of the contrast fluid.

4. *Displacement of the Large Arteries.* This group consists of expansive processes such as the retroperitoneal and mesenteric tumors (8 cases).—*Mary Frances Vastine, M.D.*

Larsson, Harry, and Palmlöv, Andreas. Abdominal aortography with special reference to its complications. *Acta radiol.*, Aug., 1952, *38*, 111–124.

The authors experimented with rabbits and showed that the general toxicity of 70 per cent umbradil is rather low and that the lethal dose far exceeds the quantity used in man. Fifty-nine cases of abdominal aortography are reviewed in which umbradil (or diiodon Leo) was used. The complications which were encountered were due not to the contrast medium but to the puncture.

Conclusions. The radiopacity of umbradil is much less than that of sodium iodide. However, there were but few cases in which the roentgenograms were useless because of poor visualization of all of the vessels. Often the result was unsatisfactory because of poor distribution of the medium. Several times the mesenteric vessels were the only ones clearly visualized even after the puncture was done at the correct level in the aorta.

A difficulty which the authors often encountered in aortography was the superimposition of vascular shadows. In case of major pathological conditions such as large tumors, this was of no importance but it was very inconvenient in the scrutiny of minor details within the renal parenchyma.

In some cases the renal arteries were very poorly filled despite a markedly opaque rendering of the aorta. Obviously, it would be desirable to be able to direct the contrast medium mainly to that vascular area which the examiner wishes to study. The renal arteries can be better visualized by a puncture near their origin. This, however, involves the risk of the contrast solution being injected into the renal artery only.

Aortography with umbradil is followed by an opacity of the renal parenchyma which, as a rule, is more dense than that seen in intravenous urography. This nephrographic effect affords valuable information about pathologic processes within the kidney; *i.e.*, tumors, cysts, circulatory changes and the like. The filling of the renal calyces and pelvis is also more pronounced when this method is used.—*Mary Frances Vastine, M.D.*

MacEwen, K. F. Abdominal aortic aneurysm. *J. Canad. A. Radiologists*, June, 1952, *3*, 42–46.

Thirteen cases of aneurysm of the abdominal aorta are reported, 12 due to arteriosclerosis and 1 of congenital origin. Syphilis as an etiologic factor was not encountered in this group of 13 white persons. The average age was 69.5 years in those due to arteriosclerosis and in the 1 congenital aneurysm, 24 years. All of the aneurysms arose below the site of origin of the renal arteries and there was no roentgenologic evidence of erosion of the lumbar vertebrae.

Previous studies have noted that aneurysms of the abdominal aorta occur more commonly in males than in females. Syphilis and arteriosclerosis are the common etiologic factors, although aneurysms of mycotic origin and as a result of abdominal trauma have been reported.

Clinically, pain in the abdomen or back is usually the first subjective symptom. The pain may be constant, intermittent, dull or boring, and may radiate downward. In many cases physical examination reveals an expansile pulsating mass accompanied by a bruit.

Plain roentgenograms of the abdomen may show a large soft tissue mass, possibly with calcification in its periphery, which is displacing the gas-filled intestine. Studies of the lower dorsal and lumbar vertebrae may show erosion or scalloping of the anterior surfaces of the vertebral bodies. Roentgen examination of the gastrointestinal tract and intravenous urography help to differentiate the tumor from intrinsic lesion of these systems by displacement of the barium-filled bowel and contrast medium-filled kidneys.

The recognition of abdominal aortic aneurysms has become increasingly important because of the improvement in vascular surgery and the possibility of cure of this condition.—*Gerald Lavner, M.D.*

Rabaiotti, Antonio. Valore ed indicazione della flebografia endossea nello studio delle affezioni venose dell'arto inferiore. (The value and indication for intraosteal phlebography in the study of venous lesions of the lower extremity.) *Ann. radiol. diag.*, 1952, *24*, 181–187.

The author utilizes the intramedullary injection of contrast medium, as advocated by Leger and Masse, to visualize the veins of the lower extremity. With the patient under general anesthesia, lying on a roentgenographic table with the head tilted up about

15°, the medullary canal of the calcaneal bone is entered by a 2 mm. gauge needle, from the lateral aspect of the heel. After injection of the medium, stereoscopic roentgenograms, using a Potter-Bucky diaphragm, are taken. Two or three sets of roentgenograms are made to visualize the veins from the ankles up to the pelvis. The material injected is 30 per cent per-iodil, and approximately 40 cc. of this substance is injected. After the introduction of the medium 50 cc. of physiological solution is injected to wash away any residual contrast medium within the bone.

The advantages listed for this methods are as follows: It is neither more difficult nor time consuming to do this procedure than direct injection into the vein; the deep veins of the leg are always well visualized; in cases of considerable edema of the leg, or a low grade infection of the skin, or thrombosis of the vein, making intravenous injection difficult or hazardous, this intramedullary procedure has a distinct advantage; the general anesthesia eliminates the effect of muscle spasm, and tilting of the table shows the condition of the veins assumed with the patient in the erect position.—*Peter E. Russo, M.D.*

PIRASTU, EMILIO. L'osteomielografia. (Osteomyelography.) *Ann. radiol. diag.*, 1952, *24*, 245–259.

Drasmer and Jennj, working independently, have proposed direct injection into the medullary cavity of contrast medium for opacification of the veins located in the vicinity of that bone. The possibility of studying bone pathology by this method has been used by the author.

The technique consists of employing a sternal puncture needle which is driven into the spongy substance of the bone. About 20 cc. of uroselectan B or ioduron are injected rather rapidly and film exposures made. Since this procedure is very painful to the patient, general anesthesia is recommended.

The author reports on 9 cases studied by this method. Several of these were cases of chronic osteomyelitis. Pooling of the contrast medium in places where bone destruction has occurred shows the extent of the disease in the involved bone. Included in this series are cases of primary bone malignancy. The vascularity of the tumor mass is easily demonstrated by this method.

The only contraindication is the presence of acute thrombophlebitis.—*Peter E. Russo, M.D.*

LEMAIRE, ANDRÉ. As injecções intra-arteriais de oxigénio; novo meio de diagnóstico e de tratamento das arterites dos membros. (Intraarterial injections of oxygen; a new method of diagnosis and treatment of arteritis of the extremities.) *Rev. brasil. med.*, May, 1952, *9*, 302–305.

Together with Loepen and Housset, the author has been experimenting, since 1947, with intra-arterial injections of gaseous oxygen in animals, a method which he has now extended to the diagnosis and treatment of patients suffering from arteritis. On account of the danger of cerebral embolism due to diastolic gas reflux into the carotid or the vertebral arteries, intra-arterial oxygen injection into the subclavian arteries is inadvisable. The main field of application of the method is therefore limited to the lower extremities, although with certain precautions (for instance, Trendelenburg position) successful injections have been made into the arteries of the upper extremities.

By means of a fine needle about 50 to 100 cc. of gaseous oxygen is injected into the femoral artery at the level of the inguinal fold. At first 200 to 300 cc. of oxygen was injected but it was determined that smaller amounts are sufficient. The injection takes several minutes, and should be confined to the diastolic phase of pulsation. During the injection an intermittent murmur, synchronous with the pulse, can be heard. Soon after the injection a marked vasoconstriction takes place in the affected extremity, accompanied by coolness and paleness of the extremity. About one to fifteen minutes after injection, this vasoconstriction is superseded by vasodilatation. The cutaneous temperature rises about 3 or 4 degrees; the skin of the extremity becomes reddened (which may last half an hour or more) and the patient experiences a feeling of warmth.

In a certain number of cases unforeseen phenomena may be observed: gas crepitation in the superficial veins at the ankle; immediate desire of micturition or defecation; lumbar pain; erythrosis of the anterior abdominal wall, the gluteal region, the perineum or the scrotum or even of the opposite limb, apparently due to the passage of the oxygen through the capillary net of the extremity. By retrograde passage the oxygen may travel to the epigastric and iliac arteries or their collaterals or even to the opposite femoral artery.

The injected oxygen does not unite with the hemoglobin of the blood because the arterial blood is already saturated with oxygen.

Patients suffering from arteritis and treated by this method reported complete disappearance of cramping and pains. This improvement lasts for fifteen to twenty days and sometimes for more than a month. According to Lemaire, the method is also of great diagnostic importance to the radiologist as it furnishes excellent arteriographic images, rich in contrast, of the arterial trunks.—*Ernst A. Schmidt, M.D.*

TORI, GIULIO. Primi esperimenti di epiepatoflebografia nell' uomo. (First experiments in epihepatophlebography in man.) *Bull. sc. med.*, Bologna, 1952, *124*, 71–75.

To the author's knowledge, this is the first effort to visualize the efferent hepatic veins in a living subject.

Visualization of the afferent veins of the liver has been accomplished by various investigators. One group has injected the portal vein directly during surgical exposure, while another group has injected the contrast medium into the substance of the spleen directly through the abdominal wall.

Rappaport described a method to visualize the suprahepatic veins in dogs by introducing a catheter into the saphenous vein, directing the tip of the catheter either into the right or left hepatic vein.

The author's method is essentially the same as is used in cardiac catheterization. The tip of the catheter is passed beyond the right atrium into the inferior vena cava. About 2 to 3 cm. below the level of the diaphragm, the hepatic veins are entered by manipulation of the tip of the catheter. The right vein, because of its position and larger caliber, is easier to enter. The catheter is passed until it fits snugly into the lumen of the vein, 20–25 cc. of 70 per cent prelosil is injected within five seconds, and exposures made at one to two second intervals. For better visualization of the liver a retropneumoperitoneum is performed prior to the catheterization.

To date 5 normal patients have been injected, and no ill effects from this procedure have been noted. Injection of the left vein has been more difficult beause of its smaller size and therefore more difficulty in inserting the catheter.

The practical applicability of this procedure remains to be determined. Its use in pathological cases may be necessary to evaluate its future usefulness.—*Peter E. Russo, M.D.*

Léger, Jean-Louis. Preliminary report on the use of a new contrast medium: Angiopac. *J. Canad. A. Radiologists.* June, 1952, *3*, 38–41.

The use of angiopac, an ethyl-di-iodo-stearate in colloidal suspension, as a medium for angiography and hepatosplenography in 23 cases is reported. The density of the vascular image compared favorably with that obtained with diodrast and there was less blood vessel irritation at the time of injection. However, delayed reactions, such as vomiting and chills, were encountered more frequently.

Angiopac as a medium for hepatosplenography was employed in 4 cases. Visualization of the liver was poor in all 4, but in 3, the spleen was well visualized. Unlike thorotrast, which is also a colloidal suspension, the new medium is not radioactive and is rapidly excreted by the kidneys.

The author does not attempt to draw any conclusions from this small series of cases. In his experience angiopac has been safe and relatively free from reactions. A final opinion must await further study, more extensive use of this new medium and careful reports of the experience of others.—*Gerald Lavner, M.D.*

Hooks, Charles A., and Graves, Oliver H. Experiences with percutaneous trans-femoral renal arteriography. *South. M. J.*, July, 1952, *45*, 587–591.

The authors describe their technique and experiences in 50 patients on whom they have performed renal arteriography by the percutaneous transfemoral route. After inserting a needle into the femoral artery, polyethylene tubing is passed through the needle into the arterial stream as far as the level of the renal arteries. After the tubing is in place, dilute heparin solution is injected into it. Thus it may be clamped and left for hours, if need be, until the diagnostic study is completed. Seventy per cent urokon sodium and 75 per cent neo-iopax were the contrast substances used.

The distinct advantage of the method is that the injection may be repeated to obtain the desired result. If need be, the position of the patient may be changed (erect, lateral, oblique) to obtain more information. In some cases, as much as 75 to 100 cc. of the contrast medium has been injected. Although no complications were encountered in the first 50 cases, gangrene of the lower extremities due to arterial embolus complicated the 51st case. This represents one of the significant dangers of the method.—*Norman Heilbrun, M.D.*

General

Henderson, J. L., MacGregor, Agnes R., Thannhauser, S. J., and Holden, R. The pathology and biochemistry of gargoylism; report of three cases with a review of the literature. *Arch. Dis. Childhood*, June, 1952, *27*, 230–253.

Three cases of gargoylism are reported. In one, biopsy specimens were examined histopathologically; in another, biopsy specimens were examined histopathologically and biochemically; and in the third, a complete necropsy and extensive biochemical studies were carried out.

The newly reported findings, together with those previously described, indicate that in typical cases almost all the tissues in the body may be affected by the same cellular lesion. The individual cells involved are enlarged by cytoplasmic swelling, and the cytoplasm may be clear, vacuolated, or granular. There is apparently an abnormal deposit or storage in the cytoplasm. The alteration of the cells presumably results in tissue abnormalities of growth and function which, in turn, produce the clinical manifestations of the disease.

Determination of the nature of the abnormal cytoplasmic deposit would seem to be the first step toward an understanding of the pathogenesis of gargoylism. On the basis of staining methods and qualitative chemical analysis, it had been thought by some investigators that the deposit is a lipoid material, and by others that it is glycogen. However,

quantitative chemical analysis, including the authors' full study, fails to support these hypotheses. In fact, their data show no increase in any lipoid fraction or in storage of pure glycogen. The nature of the deposit has still to be determined, with a glycoprotein or mucoprotein the next consideration.—*George Cooper, Jr., M.D.*

Maudsley, Roy H. A case of myositis ossificans progressiva. *Brit. M. J.*, May 3, 1952, *1*, 954–956.

The author describes in detail a case of myositis ossificans progressiva with a history from the third to the twenty-fourth year. This disease is characterized by deposits of heterotopic bone in relation to voluntary muscle.

The twenty-four year old female patient presented many of the characteristic features of the disease as described in the literature. These include: (1) onset is within the first years of life; (2) there is absence of a family history; (3) three-quarters of the cases show abnormalities in the hands and feet such as microdactyly but the author's case did not; (4) laboratory and biopsy tests fail to reveal bone abnormality; the bone appears to form in connective tissue in relation to hemorrhage; (5) no distinct sex ratio is present; (6) no relationship to infection or rheumatism is elicited; (7) trauma produces the episodes; (8) roentgen therapy has not been helpful in mobilizing the joints but prevented recurrence of the bone at the site of biopsy in buttock region; and (9) no treatment has been found to stop the relentless progress of the disease.—*Thomas D. Allison, M.D.*

RADIATION THERAPY

Stallard, H. B. Irradiation of retinoblastoma (glioma retinae). *Lancet*, May 24, 1952, *1*, 1046–1049.

The retinoblastoma is a highly radiosensitive tumor. Both eyes are affected in 40 per cent of cases, the growth being more advanced in one eye than in the other. The prospect of successful irradiation is good when the tumor affects a third or less of the retina and has not invaded the optic disc. It is, however, most unlikely that even "guiding vision" will be saved when more than one-half of the retina has been destroyed by the neoplasm. In such advanced cases, even when the retinoblastoma is completely destroyed, complications such as complete retinal detachment, severe intraocular hemorrhage, iridocyclitis and endophthalmitis render the eye blind.

The author reports on his experience in treating 29 patients with retinoblastoma with radon seeds and radium discs; 83 per cent have some useful vision and had no evidence of recurrence in the irradiated eye. Seven were alive more than five years after irradiation. He prefers to use radium discs, made to fit the scleral curvature evenly, rather than radon seeds, radium needles fixed in Columbia paste, or the radium bomb which are disastrous for the eye and quite often fail to destroy the neoplasm completely. He suggests that a dose of 2,500–3,000 r at the summit of the neoplasm and 6,000–8,000 r at its base is generally effective.

Deep roentgen therapy is successful in some cases where less than a third of the retina is affected by the neoplasm but it has the disadvantages of protracted treatment and the difficulty of maintaining the necessary immobility of a child's head during treatment, and it produces a higher incidence of serious complications.—*James F. Martin, M.D.*

Tucker, Gabriel. Diagnosis and treatment of cancer of the larynx; use of median thyrotomy, laryngectomy, irradiation, and irradiation with surgery. *J.A.M.A.*, May 10, 1952, *149*, 119–121.

The early symptoms of laryngeal cancer are hoarseness and local discomfort. Hoarseness indicates a lesion of the vocal area which includes the true cords, the subglottic larynx and that portion of the larynx described as intrinsic. Local discomfort is a symptom of the silent area which includes the ventricular bands, arytenoids, epiglottis and the external surface of the larynx. Cancers of the silent area metastasize early and are often far advanced when seen. Fortunately, at least 70 per cent of laryngeal cancers are in the vocal area.

In reviewing his cases, the author found 86 per cent of patients treated by median thyrotomy free of recurrence for five years or longer and 61 per cent similarly free when treated by laryngectomy. No details are given on irradiated cases but it is the author's impression that patients over sixty-five years of age respond better to irradiation than younger groups. He likewise feels that results of irradiation have been worth while in the types of cases treated.—*Henry J. Klos, M.D.*

Garland, L. H., and Sisson, M. A. Roentgen therapy of carcinoma of the larynx. *Surg., Gynec. & Obst.*, May, 1952, *94*, 598–604.

In early laryngeal cord cancer, roentgen therapy apparently gives as good results as surgery in terms of survival or cure, and superior results in terms of function. In advanced cord cancer, with cartilage invasion or marked secondary infection, and in extrinsic laryngeal cancer, it is believed by many that radical surgery gives chances of survival superior to those obtainable with roentgen therapy.

This paper is a report based on the authors' experience with 132 cases of cancer of the larynx treated by roentgen therapy during the last eighteen years. Sixty-nine of these cases were treated prior to 1946 and are therefore suitable for five year analysis.

Of 62 cases in which treatment was completed, 31

were clinically arrested following treatment (50 per cent); 16 of these patients died of intercurrent disease prior to the lapse of five years and 2 were lost to follow up. Of the "determinate" group of 44 cases, 13 patients were alive and well after five years (30 per cent).

Of 11 determinate cases, both intrinsic and extrinsic, classified as Stage I or II (that is, in the conventionally "operable" group) 7 patients were alive and well five or more years (64 per cent). The cure rate for the intrinsic lesions alone (Stages I and II) was 80 per cent.

Treatment. At the time of the first treatment the estimated center of the tumor was marked on the patient's skin (on either side of the neck) under fluoroscopic guidance with the patient lying on his side in the precise position he was to occupy on the treatment table. When necessary spot films were made with a small lead marker over the central point. Precision in aiming the subsequent beam of roentgen rays was considered essential and each case was set up and observed by the radiotherapist at every treatment visit.

The usual technical factors of 200 to 250 kilovolts, 15 to 25 milliamperes, half-value layer of 1 to 2 millimeters of copper, and distance of 50 to 70 centimeters were used throughout this series. Most cases were started with two directly opposing 10 or 8 centimeter circular beams and the beam size was gradually reduced during therapy when such was considered advisable—but rarely below 5 centimeters in diameter.

Except in the presence of a very narrow airway the initial dose was usually 100 roentgens in air to one lateral field. This was increased to 150 r next day, and 200 r on the third. Treatment was continued at the rate of 200 r a day to one field for another few days and, in some cases, increased to 250 or 300 r.

Treatments were given daily six days per week until the planned dose had been administered or the planned mucosal reaction produced in the larynx. In many cases the planned dose was 5,000 r to tumor in four weeks. This required about 3,000 r in air to each of the two lateral fields in twenty-eight treatment days.

When epithelitis did not appear at the expected time, treatment was continued for a few additional doses but rarely to exceed a total of 3,500 r in air to each side of the neck.

The epithelitis present at or near the end of treatment usually took two to four weeks to subside and, in favorable cases, the tumor usually disappeared by the time the mucosal reaction was fully healed. However, in a fair number of cases, complete disappearance of the mass or swelling in the area of the primary tumor required as long as three months following cessation of treatment.—*Mary Frances Vastine, M.D.*

MAYER, EDGAR, and ROSWIT, BERNARD. Newer palliative measures in the management of inoperable bronchogenic carcinoma. *Dis. of Chest*, May, 1952, *21*, 491–512.

In view of the increasing number of cases of bronchogenic carcinoma, the authors present some of the newer palliative measures applicable to management of inoperable bronchogenic carcinoma and also discuss their own experiences with nearly 700 cases. The modes of treatment discussed are: (1) radiation therapy; (2) nitrogen mustard therapy; (3) surgical techniques, and (4) medical procedures.

Radiation therapy was generally found to be the most effective palliative measure. In selected cases relief from distressing symptoms of cough, pain, expectoration, dyspnea, orthopnea and hemoptysis was obtained. There was also objective evidence of improvement such as disappearance of the obstructing pneumonitis, regression of parenchymal infiltration, shrinking of hilar nodes, healing of pathological fracture and relief from the superior vena cava compression syndrome.

Some of the recent advances in radiation therapy discussed are: (1) more accurate localization of the tumor; (2) new engineering aids to cross fire the tumor more accurately; (3) rotation of the patient's tumor region in the roentgen-ray beam; (4) closer approach to an optimum dosage formula; (5) reduction of local and systemic radiation reaction by using the "grid technique" to protect the skin, chemotherapy to prevent radiation pulmonary fibrosis (dicumarol), and higher voltage roentgen therapy apparatus; and (6) the use of multimillion volt roentgen-ray beams. There was less skin and general systemic reaction. Remissions lasting nearly a year have been observed in the Pancoast type of tumor using a 23 mev. betatron. Radioactive isotopes such as cobalt 60 are mentioned which give radiation similar to radium or a 2 million volt roentgen-ray apparatus. In the future massive particle accelators employed in atom smashing, such as the 70 million volt synchrotron, may be used. The betatron gives prospects of greater therapeutic efficiency in treatment of deep-seated lesions in the thorax.

The use of nitrogen mustard is discussed and 3 cases are presented. This agent was found to be a valuable adjunct in cases when irradiation was unfeasible or ineffective because of radiation resistance, intractable constitutional symptoms, advanced generalization, or acute mediastinal compression. The undifferentiated type of tumor responded the best. It is emphasized that nitrogen mustard is a systemic toxic agent capable of casuing irreparable damage to the hematopoietic system. The dosage of nitrogen mustard is discussed and also the dosage of oral nitrogen mustard (triethyl melamine or TEM). The results with TEM were equivocal. Nitrogen mustard was used with encouraging results in cases of pleural effusion by injecting it into the pleural space.

Palliative surgery can help reduce the distressing symptoms. A fairly well circumscribed lesion which is the site of necrosis, abscess and cavitation and causes severe symptoms may be resected in view of of the recent surgical advances and the availability of antibiotics. An endobronchial lesion causing obstruction of a main braonchus or overlying the carina may be repeatedly fulgurated. Painful metastatic lesions may be resected. Neurosurgery offers considerable help in relieving intractable pain. Intercostal neurectomy, phrenicectomy, cordotomy, posterior rhizotomy, exclusive of the cervical roots, and in extensive disease, a prefrontal lobectomy may be done.

Pain, cough, dyspnea, malnutrition and constitutional symptoms due to suppuration of the lung require palliative medical measures as the disease progresses. The use of narcotics is delayed as long as possible. The newer narcotics such as dromoran, demerol, methadon, metopon are preferred. Dromoran showed the best possibilities. Alternating the various narcotics is beneficial. Intravenous alcohol, 5 to 10 per cent, is helpful in relieving pain.

Steam inhalation, codeine, CO_2 inhalations, aminophylline, ephedrine and neosynephrine are useful in cough and wheezing.

Malnutrition can be dealt with by a high protein and carbohydrate diet supplemented by vitamins and minerals. Amino acids and emulsified fat by mouth are useful.

Intramuscular injections of testosterone aid in preventing a negative nitrogen balance. Cortisone helps to stimulate bone marrow activity and alleviates the toxic effect of nitrogen mustard in some cases.

The authors conclude that radiation therapy has provided the most effective and prolonged palliation and that it will become even more useful in the future.—*Charles W. Cooley, M.D.*

KAAE, SIGVARD. The value of preoperative roentgen irradiation in operable breast cancer. *Acta radiol.*, June, 1952, *37*, 568–576.

There is a marked conflict of opinion regarding the treatment of operable cases of breast cancer. This conflict applies to the criteria of operability, the kind of surgical intervention to be performed and the value of supplementary radiation therapy.

During the period 1931–1944 the treatment of operable breast cancer at the Radium Centre in Copenhagen was preoperative roentgen irradiation and radical mastectomy, in some cases supplemented by postoperative roentgen irradiation.

From 1931 to 1938, moderate preoperative roentgen irradiation was delivered to the breast and axilla and a small postoperative dose was given to the operative field. From 1938 to 1944 a heavier preoperative dose was delivered to the breast, axilla and supra-infraclavicular region. This was seldom followed by postoperative irradiation.

Conclusions. Heavy preoperative roentgen irradiation associated with radical mastectomy does not appear to offer better results than moderate preoperative roentgen irradiation in definitely operable cases ("operable" according to the criteria of Haagensen and Stout). At any rate, it has not lowered the incidence of recurrence in the irradiated area. Since breast cancer, on the whole, is rather radioresistant, it is questionable whether anything has been gained by supplementing radical mastectomy by preoperative roentgen irradiation in the cases considered operable according to the criteria of Haagensen and Stout.

In locally and regionally advanced cases, the results of radical mastectomy may sometimes be improved by initiating the treatment with heavy preoperative roentgen irradiation. This group is small, however, and the improvement obtainable appears to amount to merely a few per cent in the five year results for all operable cases. It is therefore doubtful whether systematic preoperative roentgen irradiation ought to be continued as a supplement to radical mastectomy in all operable cases.—*Mary Frances Vastine, M.D.*

NOLAN, JAMES F., and DU SAULT, LUCILLE. The elimination of untoward radiation sequelae in the treatment of carcinoma of the uterine cervix. *Surg., Gynec. & Obst.*, May, 1952, *94*, 539–542.

The material used in this study includes patients treated for carcinoma of the cervix uteri at the Los Angeles Tumor Institute between 1945 and 1950 inclusive. Two hundred and fourteen patients of the clinical Stages I, II and III were used in the preparation of this work.

The technique of treatment included the use of external roentgen therapy with the following factors: 500 kv., 5 ma., 1 mm. lead (equivalent) filter, 50 cm. skin-target distance, 6 mm. Cu half-value layer. Usually, two anterior and two posterior pelvic portals of 150 sq. cm. were used and a dosage of 150 roentgens (in air) was given to two portals daily (to a total of 1,800 r in air to each). Radium implantations were performed according to several techniques which included intrauterine tandems with intravaginal bombs, specially designed intravaginal sponge rubber colpostats, interstitial parametrial needles and also the Ernst applicator. Usually two radium implantations were used (with a two week interval between the applications) at the completion of the external irradiation. Total exposures were in the order of 6,000 milligram hours with the actual doses expressed at a certain point in the pelvis in the order of 7,000 gamma roentgens.

The Incidence of Complications. In the series of patients having more than one complication the gastrointestinal complications were the most frequent and the urinary ones the least frequent.

The Incidence of Complications in Relation to Dose. The dose of 7,000 roentgens has been used to denote a theoretically cancerocidal dose in previous studies. As might be expected, cervical necrosis or uterine inflammations do not appear dependent upon the amount of radiation delivered to this key point in the pelvis. (Actually the incidence of these complications could be correlated with other factors, such as the type of applicator and the condition of the patient, which should have more bearing on them than the total parametrial dose.) The incidence of proctitis and cystitis in relation to high or low dosage, as measured in the parametrium, indicates a dependence of this type of reaction upon dosage.

The Incidence of Successful Treatment in Relation to Complications. Although the criteria for success in this series cannot be complete because of the short term follow-up, the results have been found to follow those reported according to much more rigid criteria for an earlier and larger series.

Previous analyses have indicated that success or failure depends greatly upon the gross extent of the lesion; further, the amount of radiation delivered has been found to be of importance within each of the clinical stages. In addition to these factors, a third important point is the time in which the total dose is delivered.—*Mary Frances Vastine, M.D.*

Payne, Franklin L. The role of radiation and of surgery in the management of uterine carcinoma. *Surg., Gynec. & Obst.*, June, 1952, *94*, 715–721.

The last word has not been written concerning the treatment of carcinoma of the uterus, whether it be that of the corpus or of the cervix. The problem is in such a fluid state that no one can predict the final role of either irradiation or surgery.

Carcinoma of the Uterine Corpus. The methods and results from 1931 to 1945 are analyzed. During this time 211 patients with corpus cancer were observed by the author (at the Hospital of the University of Pennsylvania) throughout their period of therapy. Preference was given to the surgical treatment of those patients who were good operative risks (when the disease was thought to be limited to the uterus). About one-fourth received intracavitary tandem radium prior to operation while the remainder were treated by immediate surgery. For the poor surgical risks and for those with disease that had extended beyond the uterus, irradiation by intracavitary radium and by subsequent roentgen therapy was preferred.

Carcinoma of the Uterine Cervix. During the period from 1930 to 1945, three successive five year series showed the following survival rates (at the Hospital of the University of Pennsylvania): 28.6 per cent, 39 per cent, and 44.8 per cent. This improvement in irradiation results (no surgically treated patients are included) may be ascribed not only to more early cases but also to increased therapeutic achievement due to the following policies: (1) the treatment of the patient as a whole, rather than the simple attack upon the cervical cancer; (2) an alteration in the sequence of irradiation with the initial roentgen therapy and the subsequent treatment by local multiple small radium sources; (3) the concept of tissue dosage with the effort to reach proper levels by a combination of roentgen and radium therapy, and finally (4) the closest cooperation between the departments of radiology and gynecology with the individualization of each problem and frequent consultation between the senior members of both departments.

Summary. This study was made in order to crystallize our thinking as to the modern day to day management of uterine carcinoma. In cancer of the corpus the complementary use of irradiation and surgery is increasing the survival rate. For the inoperable cases, both low intensity intracavitary radium packing and roentgen therapy are indicated.

In cervical cancer, primary irradiation by external and local approaches remains the keystone of therapy, while the supplementary use of surgery has certain limited indications.

For both conditions the recent introduction of radical and ultraradical surgical measures is a commendable experimental undertaking that may add much to out therapeutic armamentarium in the future.

For the present, however, it seems to be both wise and humane not to abandon the proved methods in favor of the more dramatic and more hazardous but unproved measures in the day to day treatment of this disease.—*Mary Frances Vastine, M.D.*

Currie, David W. The association of radium and surgery in the treatment of carcinoma of the cervix. *Proc. Roy. Soc. Med.*, June, 1952, *45*, 327–331.

A series of 103 patients operated upon for carcinoma of the cervix is reported. The candidacy of the patient for surgical procedure was determined by the local extension and the patient's general condition. Age and adiposity were not considered deterring factors but concurrent disease, such as respiratory or renal disease, was regarded an excluding factor. Fifty-five per cent of all patients seen were subjected to surgery. This high figure was due to the fact that the patients were initially screened by the Leeds Radiotherapy Centre.

The radium therapy consisted of the use of 120 mg. which were divided into three separate applicators, 40 mg. in the uterus and 40 mg. in each lateral fornix. This amount was left in situ for twenty-four hours to give 2,880 mg. hr. Some patients received from two to three applications, but the majority of individuals were given only one application. Three weeks later, the operation was performed removing

the proximal 5 cm. of the vagina. The value of the preoperative radium is probably limited, and is not enhanced by giving a major dose.

Fifty-two cases were observed for radiation effect on the primary growth. In 17 per cent the tumor was destroyed histopathologically; 33 per cent showed a few remaining viable appearing cells; 40 per cent showed little effect due to irradiation; and 10 per cent showed no postirradiation change.

Twenty-six of the patients showed lymph node involvement.

No immediate postoperative deaths are recorded. One death occurred within ten weeks of operation, 8 within twelve months, and 2 occurred nearly five years later. Two cases have emigrated but are under supervision. Seven patients dying within one year of operation were not considered failures of local resection. It is believed the tumor had metastasized prior to surgery.

Postoperative complications were rare. The author did not observe an increased incidence of damage to the ureter using combined intracavitary radium and surgery.

The survival rate for five years was 79.5 per cent. The ten year survival rate was 66 per cent. The pelvic lymph nodes were not affected by the application of radium. Twenty-five per cent of the operated cases were found to have had involved pelvic lymph nodes. For this reason a cure rate by radium application alone is foredoomed not to exceed 75 per cent.—*Donald R. Bernhardt, M.D.*

Redman, T. F. Stump carcinoma; its treatment and the relation between parity and incidence. *Proc. Roy. Soc. Med.*, June, 1952, *45*, 331–334.

The incidence of carcinoma of the cervical stump is as high if not higher than of carcinoma of the cervix or of the intact uterus. Reference to the literature shows an incidence of 22 per cent stump carcinoma in nulliparous women. Sixteen per cent of nulliparous women over thirty-four years of age had an intact uterus. This group had an incidence of carcinoma of 4.7 per cent. After supravaginal hysterectomy 22 per cent showed stump carcinoma. Thirty-seven per cent of all nulliparous women over thirty-four years of age were subjected to supravaginal hysterectomy. It would seem that there is a greater incidence of stump carcinoma in nulliparous women than in multiparous women.

Radium therapy of "true" stump carcinoma has yielded 25 per cent and of "coincident" stump carcinoma approximately 26 per cent five year survival or cure rate. A series of cases of stump carcinoma treated between the years 1935–1945 showed an absolute five year salvage of 36 per cent. This result is not dissimilar from that achieved in ordinary cervical carcinoma.

Limited experience with combined preoperative radium therapy and Wertheim's type of operation in carcinoma of the cervix indicates an increased salvage rate when these two modalities are combined. —*Donald R. Bernhardt, M.D.*

Hundley, J. Mason, Jr., Diehl, William K., and Kardash, Theodore. The treatment of benign uterine bleeding with intracavitary radiation. *Am. J. Obst. & Gynec.*, June, 1952, *63*, 1234–1244.

A survey of 175 patients who received 2,000 mg. hr. of intrauterine radium for benign uterine bleeding shows that there was immediate cessation of menses in 117, and after one to four months in the remainder; 1 patient continued to menstruate for eighteen months. Of the 9 failures, 5 had fibroids, 1 was due to the use of stilbesterol and the other 3 probably had increased follicular activity due to adrenal stimulation. All received 100 mg. of radium in tandem in the uterus with 1 mm. platinum and irridium filter for twenty hours.

Intracavitary radium is used in women over forty when further childbearing is not to be considered, conservative measures are unsatisfactory, or the patient is a poor operative risk. The contraindications include large uterine tumors, ovarian tumor, pelvic inflammatory disease or blood dyscrasias. Carcinoma must be excluded and a curettage routinely done.

Histopathologically, hyperplasia was found most frequently (51), but other endometrial changes were often observed such as proliferative (41), secretory (34), atrophic (19), and others (30).

It is emphasized that the major effect of the radium is on the follicular system of the ovary while the minor effect is upon the endometrium. The end result is a corpus albicans, the ovary grossly showing fibrosis and marked diminution in size. The endometrial glands undergo marked degenerative changes so that eventually there is complete loss of endometrium.

The authors found no aggravation of climacteric symptoms produced by radiation castration. Transient leukorrhea may follow radium treatment. One patient developed a cellulitis of the parametrium.

Only 1 case of fundal carcinoma developed after radium application in a total of 225 cases, or a rate of 0.44 per 100 population, which is less than the normal expectancy of 2.5 per 100 population.—*Martha Mottram, M.D.*

Kimbrough, J. C. Tumors of the testicle; irradiation therapy. *Surg., Gynec. & Obst.*, May, 1952, *94*, 535–538.

Malignant tumors of the testicle are often mixed in type. A seminoma which appears monodermal may contain subversive elements of embryonal carcinoma, chorionepithelioma, or other highly malignant forms. These unrecognized elements not in-

frequently metastasize independently of the seminoma. The structural patterns of the malignant tumors of the testicle may be classified as follows, so far as treatment is concerned: (1) radiosensitive—seminoma; (2) radioresistant—embryonal carcinoma, teratoma, teratocarcinoma, chorionepithelioma, and miscellaneous.

Tumors of the testicle metastasize first and most frequently by the lymphatics but may metasize by the blood stream. Early metastases by the lymphatics are unilateral and located in the lumbar lymph nodes situated between the bifurcation of the aorta and the renal pedicle. The disease is curable by radical resection of these lymph nodes provided the operative treatment is accomplished before generalized dissemination has occurred.

The prognosis in patients with testicular neoplasms depends mainly on three factors: (1) structural pattern, especially whether radiosensitive or radioresistant; (2) stage of development of disease. Mere time does not determine the stage since some tumors remain local for months while others explode in a few weeks; (3) the type of treatment. (The treatment of choice in all malignant tumors of the testes is early radical operation—orchiectomy and resection of lumbar lymphatics, followed by appropriate radiation therapy.)

Seminoma gives the best prognosis because it is of low grade malignancy, metastasizes late and is radiosensitive. However, since the seminomas may metastasize as a radioresistant type, radiation therapy alone cannot be depended upon to control the tumor.

At Walter Reed Hospital, 1,000 kilovolt therapy is used. Tumors of different structural patterns require different dosages of radiation. The lethal dose for the seminoma is 500 to 1,000 roentgens administered in two weeks or 2,000 r in four weeks. Trophocarcinoma and adenocarcinoma have a lethal dose of 3,500 to 4,000 r in two weeks. Chorionepithelioma requires 4,000 to 5,000 r in two weeks. Teratocarcinoma may require up to 6,000 r to be effective in two weeks.

Any dosage above 4,000 r in a period of less than four weeks is hazardous and should be used with caution and only in extreme cases.

Preoperative irradiation is not given at Walter Reed Hospital. Treatment is started seven to ten days following operation. It is probable that irradiation does not interfere with wound healing and may be started immediately after operation. However, it is advantageous to wait a few days in order to evaluate the structure of the tumor and to permit the patient to have a few days postoperative recovery. The lymphatic drainage channels of the involved testicle are also irradiated. The treatment fields extend from the external inguinal ring to the diaphragm anteriorly and posteriorly. Those patients in whom retroperitoneal metastases were found at operation are irradiated from the diaphragm upward through the mediastinum and left supraclavicular areas. The 1,000 kilovolt unit is used and 2,000 r in fifteen days for seminoma and 4,000 r in twenty-five days for all other types are administered. (A tumor dose of 4,000 r is considered the maximum permissible dose in the abdomen using 1,000 kv. therapy.)—*Mary Frances Vastine, M.D.*

Lawrence, Knowles B., and Lenson, Norman. Reticulum cell sarcoma; report of a thirteen-year survival following one thousand roentgens of x-ray therapy. *J.A.M.A.*, May 24, 1952, *149*, 361–362.

The authors report survival of a patient following irradiation for recticulum cell sarcoma after a period of thirteen years. They point out that the usual life expectancy is six to twenty-four months and that the ultimate prognosis is poor.

The case reported by the authors was that of a surgically inaccessible reticulum cell sarcoma given only 1,000 r of external radiation. The authors also indicate that much higher dosage should probably be employed in irradiating this particular type of neoplasm.—*Moris Horwitz, M.D.*

Mueller, Harry L., and Flake, Carlyle G. Irradiation of the nasopharynx in children with infectious asthma. *New England J. Med.*, June 12, 1952, *246*, 924–927.

Forty-one children with asthma of over two years' duration associated with respiratory infection were treated by roentgen or radium irradiation of the nasopharynx. Treatment consisted of the direct application of 50 mg. radium in the standard monel metal applicator to each side of the nasopharynx in a series of 26 children. In another series of 15 children, roentgen irradiation was used, 100 r being given twice, one to three weeks apart. In the radium treated group each child received a series of three applications, one to four weeks apart, the total dose on each occasion being 100 mg. for eight to ten minutes.

Of the entire group, 27 per cent obtained complete relief for periods from two to four years; 41 per cent obtained excellent results for periods of eighteen months to four years; 12 per cent obtained only a fair result and in 20 per cent results were unsatisfactory. Good results are chiefly dependent on reduction in frequency and severity of respiratory infections.—*Chauncey N. Borman, M.D.*

Koch, Wilhelm, and Reske, Werner. Die Ergebnisse der intravenösen Thorium X-Behandlung bei der Spondylarthritis ankylopoetica (M. Bechterew). (Results from intravenous administration of thorium X in treatment of ankylosing spondylitis [M. Bechterew].) *Strahlentherapie*, 1952, *87*, 439–457.

Thorium X, in contrast to thorium or thorotrast, is a pure *alpha*-emitter with a half-life of 3.64 days. It tends to localize in freshly calcifying or ossifying tissue. The authors have administered it intravenously in doses of 200 e.s.u. per week and not more than 10–12 injections in a three month period. This dosage has produced no ill effects and late damage has not been demonstrable from thorium X administered as much as ten to thirty years ago.

After four years of experience in treating ankylosing spondylitis with thorium X coupled with a basic medico-orthopedic management, the authors conclude that not only does such treatment relieve the patients' pain, but also improves mobility of the small vertebral and costal joints and the larger joints providing ankylosis has not yet occurred.—*Henry G. Moehring, M.D.*

BROWN, JAMES BARRETT, and FRYER, MINOT P. Hemangiomas: treatment and repair of defects; report of minimal radiation dosage and of multiple suture procedure. *Surg., Gynec. & Obst.*, July, 1952, *95*, 33–44.

HEMANGIOMAS: (1) *The arterial type* is probably the only hemangioma that is neoplastic, the others being on a congenital anomaly basis. The uncontrolled development of an arterial hemangioma sometimes takes place because of the mistaken idea that all of these tumors undergo spontaneous regression. They may occur anywhere on the skin or mucous membrane. Interstitial irradiation in minimal dosage is sometimes indicated for treating arterial hemangiomas. One-tenth millicurie gold radon seeds are used, one seed for each cubic centimeter of hemangioma.

(2) *Port-wine stains* or capillary hemangiomas consist of dilated superficial capillaries. These hemangiomas are not radiosensitive.

Cavernous angiomas consist mainly of veins and venous spaces. If there is an arterial element it is minimal. These angiomas may occur intracranially (the Sturge-Weber syndrome).

(3) *Spider angiomas* do not usually require any treatment. They start in childhood as a small red dot from which fine small vessels radiate. Destruction of the central feeding vessel can be done with a small cautery.

(4) *Blood lakes* consist of a dilated vein or several veins located close to the surface of the skin.

(5) *Localized vascular rupture* of small arterioles located near the surface of the skin frequently occurs.

(6) *Sclerosing hemangioma* is a term applied to a hard, brown or bluish tumor occurring just beneath the skin measuring not over 1 cm. in size. Grossly, this tumor may be confused with the nevus.

(7) *Mongolian blue spots* are bluish or bluish-black areas in the sacrococcygeal or lumbosacral region which measure several centimeters in diameter. They usually disappear in early childhood.

(8) *Lymphangiomas and hygromas* are probably related to hemangiomas as far as their origin is concerned. These tumors appear as cystic masses in infancy, usually in the neck. They are filled with straw-colored fluid and are made up of flat endothelium-lined spaces.

(9) *The solid endothelioma* is the type of hemangioma in which there is a preponderance of solid, typical endothelial cells with relatively few vascular channels. This tumor is malignant in that it invades and destroys but it does not metastasize. If these tumors cannot be removed surgically, irradiation may cause some regression.—*Mary Frances Vastine, M.D.*

MCCORMICK, NORMAN A. A study of the complications resulting from treatment of cancer of the cervix. *Canad. M. A. J.*, July, 1952, *67*, 25–28.

Sequential irradiation consisting of 200 kv. external pelvic roentgen therapy followed by radium application in an intrauterine tandem and then a vaginal colpostat was used in the treatment of 369 women with primary or recurrent cancer of the cervix. One individual directed the entire course of irradiation.

Complications from 1935 to 1939 were 23.6 per cent, from 1939 to 1948, 6.5 per cent and 2.5 per cent thereafter. Five year absolute survival rate was 33 per cent in the first and 49 per cent in the second group. Complications primarily involved the bladder and rectum but in most instances were of temporary nature. No small bowel damage or femoral neck fractures were seen.

The author calls attention to the dangers of injury with re-treatment.—*Alexander S. Macmillan, Jr., M.D.*